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FORECAST AND ANALYSIS OF INTERNATIONAL AIR TRAFFIC IN RELATION TO TRANSOCEANIC COMMUNICATION REQUIREMENTS

SUMMARY REPORT

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December 1977

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16. Abstract

This summary report presents 1975 estimates and forecasts through 1995 of international air traffic and peak Instantaneous Airborne Counts (IACs) developed by SRI International for use by the Federal Aviation Administration in relation to transoceanic communication requirements. Data are presented here for the Atlantic Ocean basin area lying between 10° east and 80° west longitude and including South American and African continental traffic likely to enter a satellite ATC environment; for the Pacific Ocean basin running from 120° west to 120° east longitude; and the Indian Ocean basin running from 120° east to 60° east longitude. For the Atlantic basin peak basin IACs are forecast to double by 1995 under a low estimate and quadruple under the high estimate. For the Pacific basin they are forecast to more than double under the low estimate and more than quadruple under a high estimate, and for the Indian basin they are forecast to increase over 1 1/2 times under the low estimate and quintuple under the high estimate. The report describes the future travel demand, institutional and technological market environments in which air traffic and aircraft movements will be generated, models developed for forecasting air travel, aircraft movements, and counting IACs and how these models are used to develop the peak IACs.

FAA Report FAA-RD-77-131, I Summary Report Appendix I and FAA Report FAA-RD-77-131, II both dated December 1977, and FAA Report FAA-RD-76-15; Forecast and Analysis of International Air Traffic, Atlantic Ocean Basin, contain supplementary dates and methodology upon which this report is based.

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METRIC CONVERSION FACTORS

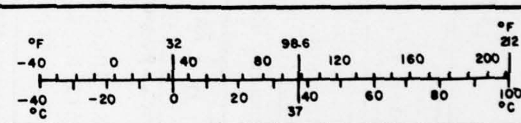
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This document is a summary report on SRI International's overall study to assist the Federal Aviation Administration in evaluating transoceanic aircraft communication requirements. The information developed was intended to provide estimates of the amount of aircraft activity over the Atlantic, Indian and Pacific Ocean basins that could potentially benefit from an operational aeronautical satellite COM/NAV and surveillance system so located that it could be used by aircraft operating in these basins. Furthermore, the forecasting system which generates these estimates was developed to accept different parameter assumptions. This enables the system to forecast aircraft activity based on alternative future scenarios.

This research was performed for the Systems Research and Development Service of the FAA (ARD-230). The assistance and cooperation of the Federal Aviation Administration is acknowledged, particularly the contributions of the FAA Contracting Officer's Technical Representative, Mr. David Spokely (ARD-230), Dr. John Scardina (ARD-230) and Bernard Hannan (AVP-120). Mr. Spokely and Dr. Scardina participated in the development of the concept of instantaneous airborne count (IAC) areas for subdividing ocean basin areas.

Mr. David Spokely's contributions were particularly important to the success of this project. He endured the many problems with data base inadequacy and trials and tribulations in the modeling effort patiently throughout. His continued faith in the worth of the forecasting concept gave constant encouragement to the SRI Project Team through many difficulties and obstacles. He made repeated efforts to enable Project Team members to understand the relationship of their work to the practical requirements for improving overocean COM-NAV and surveillance technology. He insisted that the modeling effort be developed with the capability of serving many FAA and industry aviation activity estimating

needs rather than be limited to those of transoceanic communications systems. This broader interest was clearly demonstrated when he sought and secured the concurrence of his chiefs, John Bisaga and Frank Carr, in delaying work on the Pacific and Indian Ocean Basin forecasts for what he deemed a higher priority need. This was to free the SRI Project Team to use the computer programs and forecasting models to meet an urgent requirement of the FAA Aviation Forecast Branch, AVP-120, and the FAA Office of Environmental Quality, AEQ-10, for global forecasts of aircraft movements by types of aircraft, at altitude and latitude for use in the High Altitude Pollution Program.

Responsibility for the data, assumptions, and models herein rests with the research team at SRI International. This research was conducted within the Institute's Transportation and Industrial Systems Center (TISC), headed by Dr. Robert Ratner. The research team was led by Mr. James Gorham (TISC). Dr. Randall Pozdena (TISC) developed the air traffic forecasting methodology and models. The instantaneous airborne count (IAC) methodology and model was developed by Mr. Jerome Johnson (TISC) and Mr. Robert Garnero of the Institute's Naval Warfare Research Center (NWRC). The computer implementation models and the air traffic forecast (IAC) transfer matrices are the work of Mr. Garnero and Dr. John Bobick (TISC). Mr. David Marimont (TISC), under technical direction of Drs. Bobick and Pozdena, was responsible for all computer operations relating to work on the Pacific and Indian Ocean basins.

The analyses of the traffic forecasts, peak instantaneous airborne counts, and diurnal traffic patterns for the three ocean basins and the IAC areas for these basins presented herein were conducted by James Gorham in the Transportation and Industrial Systems Center's Washington office, assisted by Dorothea Claus Gross and Dennis Yee. The base maps showing the relationship of IAC areas to FIRs for each basin were prepared by Mr. Arne Hungerbuhler, who also prepared histograms of the diurnal activity in each of the basins and their constituent IAC areas and otherwise assisted in the preparation of this summary report.

This summary report and two supporting appendices were written by Dr. Randall Pozdena, James Gorham, Dorothea Claus Gross and Dennis Yee.

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I INTRODUCTION

This report summarizes the work of SRI International (formerly Stanford Research Institue) for the FAA in developing forecasts and analyses of international air traffic in relation to transoceanic communication requirements. This section presents the background giving rise to this research, the objectives and scope of this research effort and also includes an outline of the arrangement of this report.

A. Background of the Study

Present oceanic air traffic control (ATC) systems are essentially manual. There is no radar surveillance, and the high frequency (HF) communication systems used (compared to the very high frequency, VHF, and the ultrahigh frequency, UHF, systems used in the United States and European communications and ATC systems) are sometimes unreliable and subject to fading. Consequently, aircraft flying over congested areas such as the North Atlantic Ocean are separated by a distance of 60 to 120 nautical miles to assure in-flight separation.

The areas most in need of an improved system because of high traffic volume are the North Atlantic (NAT) and the Central East Pacific (CEP). As traffic grows in other parts of the Atlantic, Pacific and Indian basin areas, a need for improved systems will arise in these regions as well. Also most of Africa and large parts of South America are presently dependent on HF systems and could also benefit from an improved communication, navigation and surveillance system. If an improved system is implemented for the NAT and CEP areas, it is impossible that it could also be used by the thousands of daily short-haul (400 n.m. and under) aircraft movements in the Latin American-African areas. In fact, some African governments have already shown an interest in exploring this possibility.

Many proposals have been put forward for improvements in the existing transoceanic communication system. These include conversion of HF to a single sideband system which would expand its capacity, combining HF with a data link and an inertial navigation system, combining HF with a data link and the NAVSTAR Global Positioning System (GPS), or replacing HF with a satellite communication, navigation and surveillance system.

The feasibility of one variant of the latter system had been explored by the United States, Canada, and nine European countries (combined in the European Space Agency, ESA). They examined the possibility of using two geostationary satellites to provide voice and data communication and surveillance for aircraft traversing ocean areas. Other possible SATCOM systems under consideration are the United States MARISAT, the European MAROTS and a projected joint U.S.-European system called IMMARSAT, as well as possible combinations of SATCOM systems with GPS.

In keeping with U.S. Congressional directives to conduct feasibility studies of the AEROSAT program, the FAA proposed to the AEROSAT Council on September 15, 1977 the establishment of a committee to provide recommendations to the Council for restructuring of the AEROSAT program to more fully meet provider/user needs. The committee would consist of high level representatives of civil aviation from the provider states and from the user community. The FAA would support the committee with the feasibility studies and analyses authorized by the U.S. Congress.

The FAA Satellite Study program will include:

- Concept definitions based on forecasted requirements;
- Technical and economic analysis of alternative concepts;
- Consideration of institutional factors such as financing, availability of services, equitable payment for services;
- Comparisons and trade-off studies of satellite systems against non-satellite alternatives;

- Selected technology development; and
- Limited system experimentation and testing.

As recognized by the FAA's Satellite Study program proposed to the AEROSAT Council, described above, to assess the future requirements for, and evaluate alternative communication, navigation and surveillance system (concepts), it is necessary to know the future demands that will be placed on the proposed systems. These demands will depend on the expected number of aircraft movements over ocean basins or land masses, as measured by an instantaneous airborne count (the total number of aircraft within a given space and period of time).

The Aviation Forecast Branch of FAA AVP-120 historically had forecasted U.S. carrier domestic and international operations, but not total international operations. Because of their interest in enlarging the FAA capability in this respect, FAA's Aviation Forecast Branch cooperated closely with both the Satellite Branch of SRDS and SRI throughout this research and provided significant technical assistance and inputs. Gene Mercer, Branch Chief, detailed Bernard Hannan for this function. On the completion of the Atlantic basin area forecasts (Report No. FAA-RD-76-15), the Aviation Forecast Branch commissioned SRI to develop a forecast of worldwide aviation activity by latitude and altitude (Report No. FAA AVP-76-18) and then had SRI put the programs for the models on their computers (Report No. FAA-AVP-77-14).

In addition to the lack of adequate forecasts of overocean traffic and aircraft movements, data were lacking on peaking of traffic over ocean basins as a whole or particular geographic subdivisions such as Flight Information Regions (FIRS). Such peaking of traffic movements is best measured by peak instantaneous airborne counts (IACs) for specified areas and periods of time (such as peak hour busy day). While some international instantaneous airborne counts have been made for some areas, no comprehensive and consistent body of data existed. Furthermore, FAA's Systems Research and Development Service wanted to develop a forecasting system and a continuously updated forecast data base that could

provide revised forecasts, as factual data or assumptions changed, new data became available or in response to different needs. To satisfy these needs, the FAA commissioned SRI to develop a flexible forecasting system and forecasts of international air travel.

B. Objectives, Scope and Content

The objectives and scope of this research effort were to:

- Develop a forecasting system sensitive to varying assumptions respecting socioeconomic, political and institutional forces that affect the demand for air travel, the frequency and diurnal distribution of traffic and aircraft movements.
- Base this system on an interactive demand/supply econometric model that permits the association of changes in influential variables with changes in the use of air transportation, and therefore permits direct manipulation of the basic inputs to test the effects on the demand and supply of air transportation services of alternative assumptions respecting such elements as costs of fuel, labor or capital or changes in per-capita GNP or population in origin and destination regions.
- Develop a system capable of determining the temporal distribution of aircraft movements, counting the movements over ocean basins and defined subareas to establish for specified latitudinal and longitudinal limits, the instantaneous airborne counts over the busy day and peak-hours IACs for the busy day.
- Demonstrate these forecasting and IAC counting systems by using them to forecast through 1995 the annual and busy day aircraft movements and the IACs for the peak hour of the busy day for the Atlantic, Indian and Pacific Ocean basins and defined subareas (including continental African and South American traffic likely to enter a satellite ATC environment).
- Conduct an analysis of the sensitivity of the system and its resulting forecasts to varying assumptions respecting input data, such as costs of fuel and non-fuel input resources, per capita GNP and population growth rates for origin and destination countries and/or regions.

This research effort resulted in the development of a forecasting system based on a market-derived computer-based econometric model. This model relates changes in the demand for, and supply of air transportation services to basic variables, exogenous inputs to the forecasting system. Forecasts can be revised or updated as desired by inputting new socio-economic, institutional or technological data or used to test the effect of alternative assumptions respecting demand or cost factors that may result in different projections of air traffic and aircraft movements.

This basic econometric model once calibrated, was used to drive other models. Using the Official Airline Guide* scheduled flight information as an input, these models generated specific outputs. These other models developed and used in this and related work include:

- a charter activity model
- a general aviation activity model
- a fleet transition model which forecasts the evolution of aircraft fleets that result from changing economic and technological conditions
- time/space allocation models

Since fairly extreme manipulation of the basic activity forecasts is required to produce the activity measures needed--such as peak IACs--the number of input assumptions that could practically be explored was severely constrained. Therefore, many of the variables that in earlier models have been part of the input assumptions are endogenous to this model, reducing the input requirements of the forecasting process. Assuming basic soundness of the model, this also narrows the possibility of employing inconsistent assumptions in a forecast (i.e., inconsistent traffic forecast, aircraft size and load factor assumptions).

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Also, since forecasts were to be developed covering a span of 15 to 20 years, it was necessary to explicitly embody assumed changes in aircraft technology in the forecasting process.

Derivation of aircraft movements associated with passenger travel in this forecasting system depends on the simultaneous interaction between two models reflecting demand and supply functions. The underlying assumptions of our approach are that tripmaking decisions depend not only on enabling factors such as origin/destination demographic and socioeconomic developments, but on fare (cost), flight frequency, and quality of service, while service offered--price and frequency--depends in turn on availability of demand and expected earnings.

Thus, the demand model relates passenger trips to average fare, number of flights and aircraft size together with the products of the respective origin and destination regional per capita income and population.

The supply model is based on assumed carrier profit maximizations in relating costs to the number of flights--and aircraft types offered. The model recognizes that air carrier costs depend on the number of flights, average aircraft size, stage length, labor rates and fuel price per gallon. Fares lag costs; and fleet purchases, as well as schedule changes, tend to lag demand.

Most forecasting models in use today do not permit direct manipulation of input variables as does our modeling system. Either these variables are not in the model at all or they are subsumed in other variables, so that they cannot be experimented with separately by the forecaster. Few air transport demand models include air carrier operating costs at all in their specification, although this is an essential element of our forecasting system. Special disaggregations of cost (labor, capital, fuel) are even rarer inclusions in demand models.

It is believed that the use of interacting demand/supply models, with many demand and cost factors embedded in them, to drive specific traffic and aircraft movement forecasting and counting models provides the FAA with a flexible tool superior to conventional demand models typically offered in the past.

Given proper parameters or input data, these models are capable of adaption to a wide range of applications. Linked to specially designed counting models, they have been used by the FAA to estimate future communications/navigation/surveillance system work load as measured by peak hour busy day IACs. They have been used to estimate savings to air carriers in terms of operation and reduced fuel costs through use of more optimum time tracks made possible by satellite communications, navigation and surveillance systems. They have been used to produce global estimates of aircraft by type at altitude and latitude to measure pollution generation for the High Altitude Pollution Program. The models also could be adapted, linked to appropriate counting models, to estimate fleet energy savings of proposed air carriers energy efficiency operations or technological developments, the noise reduction potential of alternative noise abatement concepts or technological developments, and the noise/energy impacts of alternative air carrier options to comply with the operating noise limits of FAR 36.

As noted above, they can estimate the impact of alternative fare, fuel and non-fuel cost changes, proposed service level changes and hence, in the long run, demand for aircraft, air transportation, air traffic control and navigation and airport facilities and services.

Properly calibrated, they can provide a basic tool in the assessment of the economic viability of alternative advanced aeronautical technology concepts. They can be linked to models for estimating the operating costs and performance of advanced technology, fuel efficient, environmentally acceptable aircraft and engines. They can thus be used to measure the alternative returns on the investment that can be generated with given alternatives, operating and performance characteristics, traffic, fares, earnings and

aircraft costs and payment schedules. Conversely, they can estimate a range of acceptable aircraft prices in relation to operating performance characteristics and desired ROI. Thus, they are potential tools for cost, price, fare, market, energy and noise analyses and analysis of supporting system requirements including ATC&N facilities and services.

For purposes of this study, this forecasting system is capable of generating forecasted levels of intercountry and interregional traffic, which in turn are used to estimate instantaneous airborne counts for broad ocean basins and defined geographical areas within them. The forecasting process yields statistics describing the temporal distribution of aircraft movements that determine the instantaneous airborne counts by hourly and six-minute intervals. Since the forecast aircraft movements (IACs) are derived from interregional or intercountry routes, the origin of aircraft contributing to the area activity can be determined.

For each of the three major work ocean basins, estimates were made for "scheduled" traffic and for "all traffic" and are subdivided between traffic with stage lengths of 400 nautical miles or less*, stage lengths greater than 400 nautical miles, and flights of all stage lengths. High and low forecasts were provided for each stage length and traffic category for the forecast years based on optimistic and pessimistic assumptions respecting future technological changes and cost developments in significant input resources such as fuel and labor. Diurnal activity for the base year for each of the basins and its constituent areas is presented graphically. The relative influence of long- and short-haul traffic is discussed.

The system was initially developed and tested by forecasting aircraft movements and peak instantaneous IACs for the Atlantic basin. Forecasts for the Atlantic basin and its subareas were developed at five-

* The 400 n.m. stage length was selected as being twice the distance--200 n.m. of extended range VHF communications. For purposes of this study, aircraft operating routinely over stage lengths less than 400 n.m. would not be required to carry long-range communications equipment such as satellite avionics.

year intervals for the years 1980, 1985, 1990 and 1995. The forecasts and analysis of international air traffic over the Atlantic basin have been documented in a previous report; however, these forecasts and analyses are included in this report.

Forecasts for the Pacific and Indian Ocean basins were generated for the years 1985 and 1995. Forecasts on a ten-year interval were deemed adequate for these basins because the interest was primarily in long-term development. These forecasts and analyses are included in this report.

Each of the ocean basins was divided into subareas to facilitate a more detailed analysis of aircraft movements within a particular basin. In the Atlantic basin an attempt was made to approximate Flight Information Regions (FIRs)as the basis for defining the subareas within this basin. This was done to the maximum extent possible, recognizing that there were too many FIR areas for the estimated total number of subdivisions that could be analyzed. Such a limitation was caused by the enormous memory storage requirements of the IAC counting module, which limited the memory storage capacity available for other purposes. As a result of these limitations, the Atlantic basin was subdivided into 25 subdivisions or IAC areas. These areas represent approximations, combinations or subdivisions of true FIRs.

The attempt to approximate FIRs unduly fragmented interregional traffic patterns, resulting in additional effort and expense to obtain detailed information on major traffic flows such as the North Atlantic. In the Pacific and Indian Ocean basins this problem was avoided by subdividing each basin into rectangles that more closely related to actual or anticipated traffic flows in the basins than to existing patterns and boundaries of FIRs. The eleven IAC areas or subdivisions of the Indian basin were developed in cooperation with FAA's contracting officer's technical representative and other FAA personnel.

The borders of these rectangles were, for the most part, drawn through airports serving major traffic centers or transfer points such as Honolulu, Anchorage, Tokyo, Guam and Sydney in the Pacific basin. In the Indian basin the major airports used were Hong Kong, Bangkok and Singapore. Base maps showing these IAC areas for the Pacific and Indian Ocean basins are presented in this report.

The methodologies developed for the overall forecasting effort were examined in light of circumstances peculiar to the Pacific and Indian basins and, where circumstances warranted and available data permitted, modifications were made to adapt the model more precisely to the characteristics of Indian and Pacific basins. For example, it was found that the Indian and Pacific basins appeared to be characterized by considerably lower charter shares than did the Atlantic. A special analysis was made of the problems of restrictions on overflights over primarily Communist-dominated areas of Central and Eastern Asia, and special studies were made of region pair contributions to the activities of the specific IAC areas in each basin.

C. Report Arrangement

This report consists of three statements:

- A summary statement
- A tabular forecast appendix
- A forecast assumptions and methodology appendix

The summary statement is divided into the following three sections:

I. Introduction--This section provides a brief overview of the origin of the study, the objectives, scope and content of the study and report arrangement.

II. Forecasts and Analyses--This section presents and briefly discusses the forecasts and analyses developed for the Atlantic, Pacific and Indian Ocean basins.

III. Forecast Assumptions and Methodology--This section provides an overview of the assumptions concerning the future aviation market environment, focusing on travel, institutional, technological and resource environments affecting future international air travel. Furthermore, the essential elements of the methodologies used to develop forecasts of air traffic and the conversion of these forecasts into estimates of instantaneous airborne counts are included. Also, a brief discussion of the forecasting systems sensitivity to different assumptions is provided.

The forecast appendix provides tables containing additional data used for forecasting and analyzing peak IACs for the Atlantic, Pacific and Indian Ocean basins.

The forecasting assumptions and methodology appendix provides a more detailed discussion of our assumptions concerning the future aviation environment, the forecasting system methodology and the sensitivity analysis.

II FORECASTS AND ANALYSES

A. Overview of the Forecast Findings

For the Atlantic basin the busy day (the day when most flights were performed over the basin) was determined by the dominant North Atlantic traffic flow and was found to be Friday (Greenwich time) during the June-September season. Because the areas involved are much larger and the basins are characterized by several important traffic flows, it was more difficult to establish the busy season and the busy day for the Pacific and Indian Ocean basins. Since the two ocean basins, the Pacific and Indian, are influenced by the same broadly defined inter-regional traffic flows that interact with North American, European and African activity,[1] September was chosen as the most characteristic seasonal basin peak and the peak day was Greenwich Friday for both the Pacific and the Indian Ocean basins.

For the Atlantic Ocean basin, 1600 hours Greenwich time was found to be the peak hour for flights of all stage lengths and there were 515 "scheduled" and 875 "all traffic" movements for base year 1975 for the busy hour of the busy day, Greenwich Friday in the June-September season. This traffic is projected to grow to 2,010 movements for 1995 for "scheduled only" traffic for the busy hour in the high estimate and to

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[1] For example, traffic moving from Europe by the polar route through Anchorage, Alaska to Tokyo would contribute to the North Atlantic peak IACs as well as the Pacific. If it went on to Hong Kong or Singapore it would contribute to the Indian as well. Similarly, traffic to and from Europe moving either through the Midddle East or the USSR and the Peoples Republic of China to Tokyo or Sydney would contribute to Indian and Pacific peak IACs as well as European.

1,038 in the low estimate. "All traffic" is projected to grow to 3,269 movements for 1995 in the high estimate and 1,978 in the low estimate. Thus, traffic is assumed to more than double in the low estimate and nearly quadruple in the high estimate by 1995.

For the Pacific Ocean basin, 0300 hours Greenwich time was found to be the peak hour for flights of all stage lengths and there were 360 "scheduled only" flights and 396 "all traffic" flights estimated for 1975 for that hour. These are estimated to grow for "scheduled only" to 793 for the low and 1,573 for the high estimate. "All traffic" is estimated to grow to 881 for the low estimate and 1,727 for the high estimate. This represents a greater than doubling of the traffic in the low estimate and better than quadrupling traffic for the high estimate.

Traffic growth estimates for the Indian Ocean basin project significantly faster growth than for the Atlantic and Pacific basins. During the peak period found for flights of all stage lengths, 0600 hours Greenwich time, there are 226 flights estimated for "scheduled only" during this period for 1975 and 234 for "all traffic". These are estimated to grow to 592 for "scheduled only" for the low estimate and 1,208 for the high estimate. "All traffic" is estimated to grow to 624 for the low estimate, an increase over 160 percent, and to 1,269 for the high estimate, more than quintupling of the traffic.

Table 1 compares the percentage growth estimated for peak hour IACs for each ocean basin from 1975 to 1995. Relative estimated growth is compared for short haul (400 n.m. or less), long haul (over 400 n.m.) and for all stage lengths, for "scheduled only" and for "all traffic". Relative growth under both high and low estimates is compared.

Table 1 confirms the above statement that traffic is estimated to grow significantly faster for the Indian than for the Atlantic or Pacific for all traffic categories: long haul/short haul/all stage lengths, high estimate/low estimate, "scheduled only" or "all traffic".

Table 1

COMPARATIVE PERCENTAGE GROWTH IN PEAK HOUR IACs FOR THE THREE OCEAN BASINS, 1975-95

AREA	SCHEDULED ONLY			ALL TRAFFIC		
	400 N.M. or Less (a)	Over 400 N.M. (b)	All Stage Lengths (c)	400 N.M. or Less (d)	Over 400 N.M. (e)	All Stage Lengths (f)
Low Forecast						
Atlantic	197.3 (14)	204.9 (16)	201.5 (16)	224.6 (14)	228.8 (16)	226.1 (16)
Pacific	210.6 (1)	228.1 (3)	220.3 (3)	212.7 (1)	231.4 (3)	222.5 (3)
Indian	257.3 (6)	269.5 (6)	261.9 (6)	259.6 (6)	275.9 (6)	266.7 (6)
High Forecast						
Atlantic	381.6 (14)	397.9 (16)	390.3 (16)	341.1 (14)	404.0 (16)	373.6 (16)
Pacific	415.2 (1)	454.5 (3)	436.9 (3)	413.1 (1)	455.5 (3)	436.1 (3)
Indian	524.0 (6)	550.0 (6)*	534.5 (16)	523.2 (6)	564.7 (6)	542.3 (6)

NOTE: The busy day is Greenwich Friday in the June-September season. Greenwich Mean Time for the peak hour is shown in parentheses.

*The peak IAC hour for 1975 for Indian basin flights over 400 N.M. was 7GMT.

Source: Tables 3, 7, and 12.

Traffic grows faster in long than short haul and generally in "all traffic" (that includes charter) than "scheduled". Charter traffic, however, is a much greater part of total traffic in the Atlantic than in the Pacific/Indian areas.

Traffic is estimated to grow faster in the Pacific than the Atlantic basin. This is shown in Table 1 as holding for all high estimates (scheduled or all traffic) and for the "scheduled only" traffic under the low estimate. But the Pacific growth rates exceed the Atlantic only for long-haul traffic under the pessimistic (low) estimate for "all traffic" (including charter).

Also, in contrast with the Indian Ocean basin, neither the Atlantic nor the Pacific show significant differences in growth rates for "all traffic" than for "scheduled only" for the high estimate and only the Atlantic for the low estimate.

Table 2 summarizes the passenger growth rate forecasts generated by the SRI forecasting system for major route segments in or between the three ocean basins and compares these with two successive passenger-kilometer forecasts recently developed by the International Air Transport Association (IATA). The two sets of forecasts, though defining traffic and route segments somewhat differently, indicate basically similar growth expectations. The SRI high/low estimates frequently bracket the IATA, but in some cases exceed and in other cases fall below the IATA estimates. The two successive IATA estimates have moved progressively closer to SRI's estimates.

The SRI/FAA air traffic forecasting system generates a wide range of air traffic activity estimates. Some of these are presented in this summary report. Others appear in Appendices I and II. Still others, deemed too voluminous to be included in this report and its

Table 2

COMPARATIVE PERCENTAGE GROWTH RATE FORECASTS FOR SELECTED AIR TRANSPORTATION MARKETS

MARKET	SRI		IATA	
	High	Low	1976-1982	1975-1981
North Atlantic	9.6	6.9	6.3	5.7
Mid Atlantic	10.1	7.5	10.5	11.7
South Atlantic	9.8	7.2	8.1	11.0
North America - South America	8.3	5.9	6.4	7.4
North America - Central America	9.3	6.7	5.7	4.4
Europe - Africa	10.5	7.1	9.4	9.4
Europe - Middle East	11.7	8.0	15.0	14.3
Europe - Far East*	12.4	8.7	9.2	9.3
North America - Far East**	10.8	7.3	6.5	6.6
North America - Australasia/Oceania***	8.9	5.8	8.0	7.5
Far East - Australasia/Oceania	10.3	7.0	-	-
Within Australasia/Oceania	8.4	5.4	-	-

* IATA "Europe/Middle East - Far East"
** IATA "North - Mid Pacific"
*** IATA "South Pacific"

SOURCES: IATA forecasts from IATA, "IATA Passenger Traffic Forecasts 1975-1981 Scheduled International Services", May 1976, and "IATA Passenger Traffic Forecasts 1976-1982 Scheduled International Services", June 1977. Forecasts are based on passenger-kilometers and indicate average annual growth rates for the periods shown.
SRI forecasts show passenger growth rates and apply through 1985.
Passenger growth rates and passenger-kilometer growth rates are comparable unless there is a change in route structure or stage length.

Appendices either appear in the appendices to the Atlantic basin report (No. FAA-RD-76-15) or are on file with the FAA as working papers. The major categories of aviation activity estimates generated in the course of this research, that do not appear in the report proper, and where they are shown or located are listed below:

- World Area Code List showing breakout of countries by OAG World Area Codes--Appendix A, APPENDIX I.
- Income and demographic growth rates for selected countries in the Atlantic, Indian and Pacific basins--Appendix B, APPENDIX I.
- Relative traffic ratios assumed for MAC activity estimates (Atlantic basin only)--Appendix C, Report No. FAA-RD-76-15
- High and low global interregional traffic forecasts of annual and busy day flight frequencies for passenger and cargo segments covering 1972, 1975 with forecasts for 1980-1995--Appendix C, APPENDIX I.
- IAC estimates by subzones.
  - Atlantic basin--Peak IACs during the busy hour of the busy day for each IAC area for the years 1975, 1980, 1985, 1990 and 1995. Low forecast, "scheduled only" traffic for three stage lengths (total traffic, 400 n.m. and less, and over 400 n.m.)--Appendix D, APPENDIX I.

    Similar data for the "all traffic" segment of the low forecast and for both segments of the high forecast--Appendix E , Report No. FAA-RD-76-15.
  - Indian and Pacific basins--Peak IACs during the busy hour of the busy day for each IAC area for the years 1975, 1985 and 1995. High forecast, "scheduled only" traffic for the three stage lengths--Appendix D, APPENDIX I.

    "All traffic" for high forecast, and "scheduled only" and "all traffic" for low forecast for all 3 stage lengths--Working papers available on file at FAA.
- For the base year 1975, for each Atlantic basin IAC area by route segment regional origin-destination pair, the total number of flights contributing to the busy basin day--Appendix E, APPENDIX I.

- Percentage distribution of flight hours by Greenwich hour for each basin and its constituent IAC area for forecast years through 1995 for high and low forecasts, three stage lengths and "scheduled" and "all traffic" segments. For the base year, "scheduled only" data for the Atlantic basin and "all traffic" for the Indian and Pacific basins--Working papers available on file at FAA.

- IACs for 6-minute intervals for busy day for base year and forecast years for each ocean basin. High and low forecasts, three stage lengths and "scheduled" and "all traffic" segments--Working papers available on file at FAA.

B. Findings: Atlantic Ocean Basin

This section presents an analysis of 1975 estimates and 1980, 1985, 1990 and 1995 forecasts of international aircraft movements and peak Instantaneous Airborne Counts (IACs) for the Atlantic Ocean basin and its constituent areas. These areas are defined as the Polar, North, Middle, and South Atlantic areas between 10°E and 80°W longitude and South American and African continental traffic likely to enter a satellite ATC environment.

The section is divided into three parts:

- Base and forecasted Atlantic Ocean basin IACs by stage length
- IACs by IAC areas and time of day
- Composition of Atlantic Ocean basin activity.

1. Base and Forecasted Atlantic Ocean Basin IACs by Stage Length

Table 3 shows that in 1975 there were approximately 875 flights of all stage lengths over the Atlantic basin in the estimated busy hour (1600 Greenwich Mean Time - GMT) and busy day (Friday). Of this total, 515 flights were "scheduled". Furthermore, 476 flights were over 400 nautical miles. Of these, 326 were "scheduled".

Table 3

FORECAST ATLANTIC BASIN IACs FOR 1975, 1980, 1985, 1990, AND 1995

Case	1975		1980	1985	1990	1995
			Based on 25 Areas			
Flights of All Stage Lengths						
All traffic	875(16)	(hi)	1158(16)	1590(16)	2247(16)	3269(16)
		(lo)	1057(16)	1288(16)	1593(16)	1978(16)
Scheduled only	515(16)	(hi)	668(16)	930(16)	1342(16)	2010(16)
		(lo)	594(16)	705(16)	854(16)	1038(16)
Flights of 400 Nautical Miles or Less						
All traffic	479(14)	(hi)	623(14)	839(14)	1158(14)	1634(14)
		(lo)	577(14)	705(14)	867(14)	1076(14)
Scheduled only	223(14)	(hi)	288(14)	397(14)	570(14)	851(14)
		(lo)	256(14)	302(14)	364(14)	440(14)
Flights Longer than 400 Nautical Miles						
All traffic	476(16)	(hi)	640(16)	894(16)	1290(16)	1923(16)
		(lo)	578(16)	704(16)	873(16)	1089(16)
Scheduled only	326(16)	(hi)	425(16)	595(16)	863(16)	1297(16)
		(lo)	378(16)	451(16)	548(16)	668(16)

Note: These data were derived using the June-September season Reuben H. Donnelley Official Airline Guide (OAG) data base for 1975 and interregional forecasts from SRI. The busy day in all cases is Greenwich Friday. The busy flight hour in Greenwich time is given in parentheses after each IAC estimate.

In 1980 there will be approximately 1,057 (low forecast) to 1,158 (high forecast) flights of all stage lengths in the busy hour/ busy day. Of this total, 594-668 will be "scheduled". Furthermore, 578-640 are projected to be flights over 400 n.m. of which 378-425 will be "scheduled".

By 1995 there will 1,978-3,269 flights over the Atlantic basin in the busy hour, 1,038-2,010 of them "scheduled". Of these, 1,089-1,923 will be flights over 400 n.m. and 668-1,297 of the long-range flights will be "scheduled".

SRI's model projects, even under "pessimistic" growth assumptions, a doubling of the "scheduled" IACs by 1995 and a somewhat higher growth for total traffic. Under "optimistic" assumptions, traffic is assumed to grow much faster and IACs for the Atlantic basin are expected to increase by almost four times.

Table 1 above, which compares the percentage growth in peak hour IACs for the three ocean basins 1975-1995, shows for the Atlantic basin that long-haul flights are projected to grow somewhat faster than short-haul (400 n.m. and less), the difference in growth rates being greatest for total traffic for the "optimistic" assumption than for "scheduled only" and for the "pessimistic" growth scenario.

These relationships are brought out clearly in Figures 1 and 2, which are derived from Table 3.[1] Figure 1 is based on the low or "pessimistic" forecast and Figure 2, on the "optimistic" forecast. These figures show separately for the "scheduled only" and for "all traffic", the respective growth in the short-haul, 400-nautical-mile-and-under traffic, and the traffic for all stage lengths. Figure 2, the "optimistic" or high forecast, clearly demonstrates that long-haul traffic growth exceeds the growth rate in short-haul traffic.

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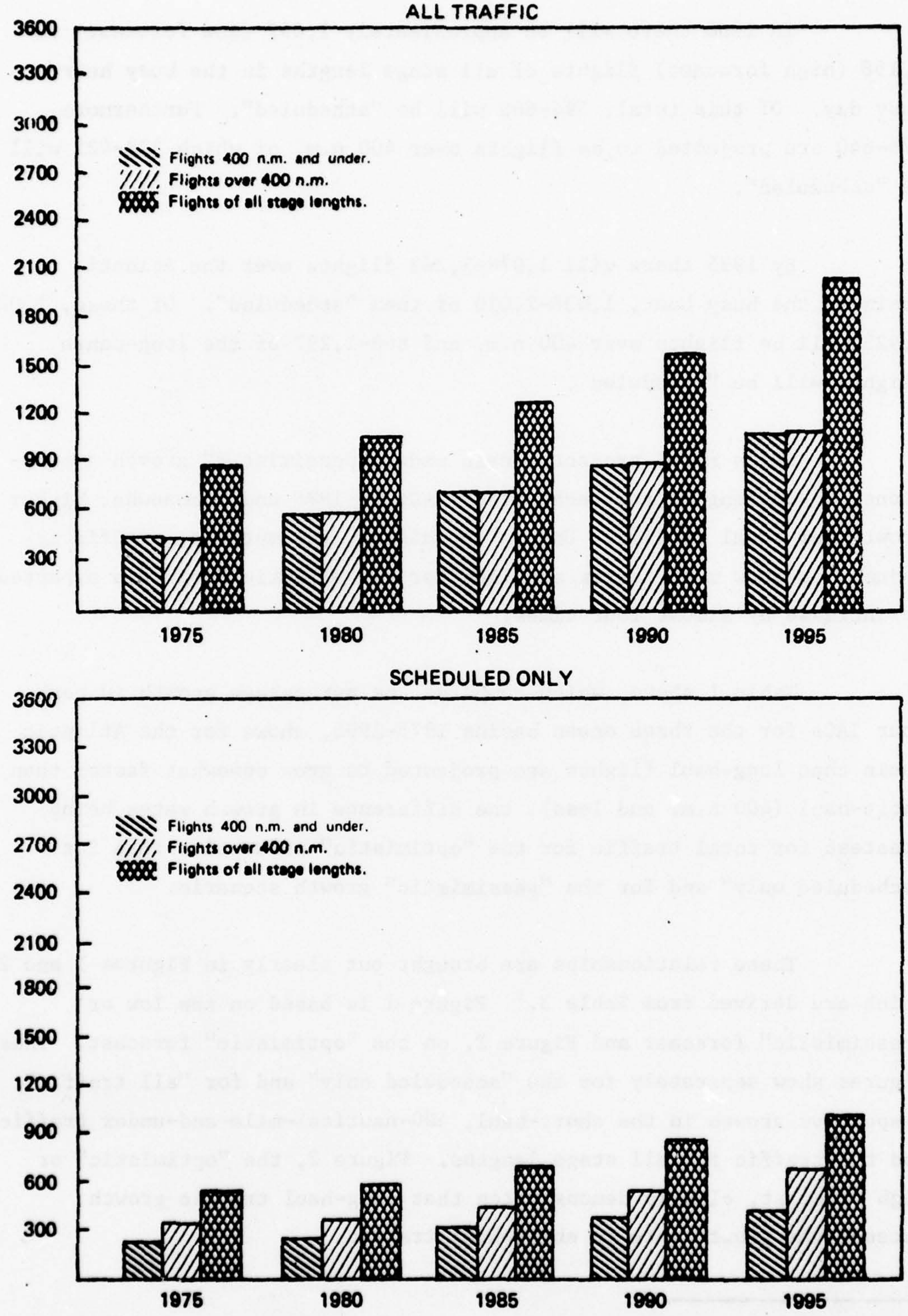
[1] The 1975 data for "scheduled only" and for "all traffic" are, of course, the same in Figures 1 and 2, there being no high and low estimate for 1975.

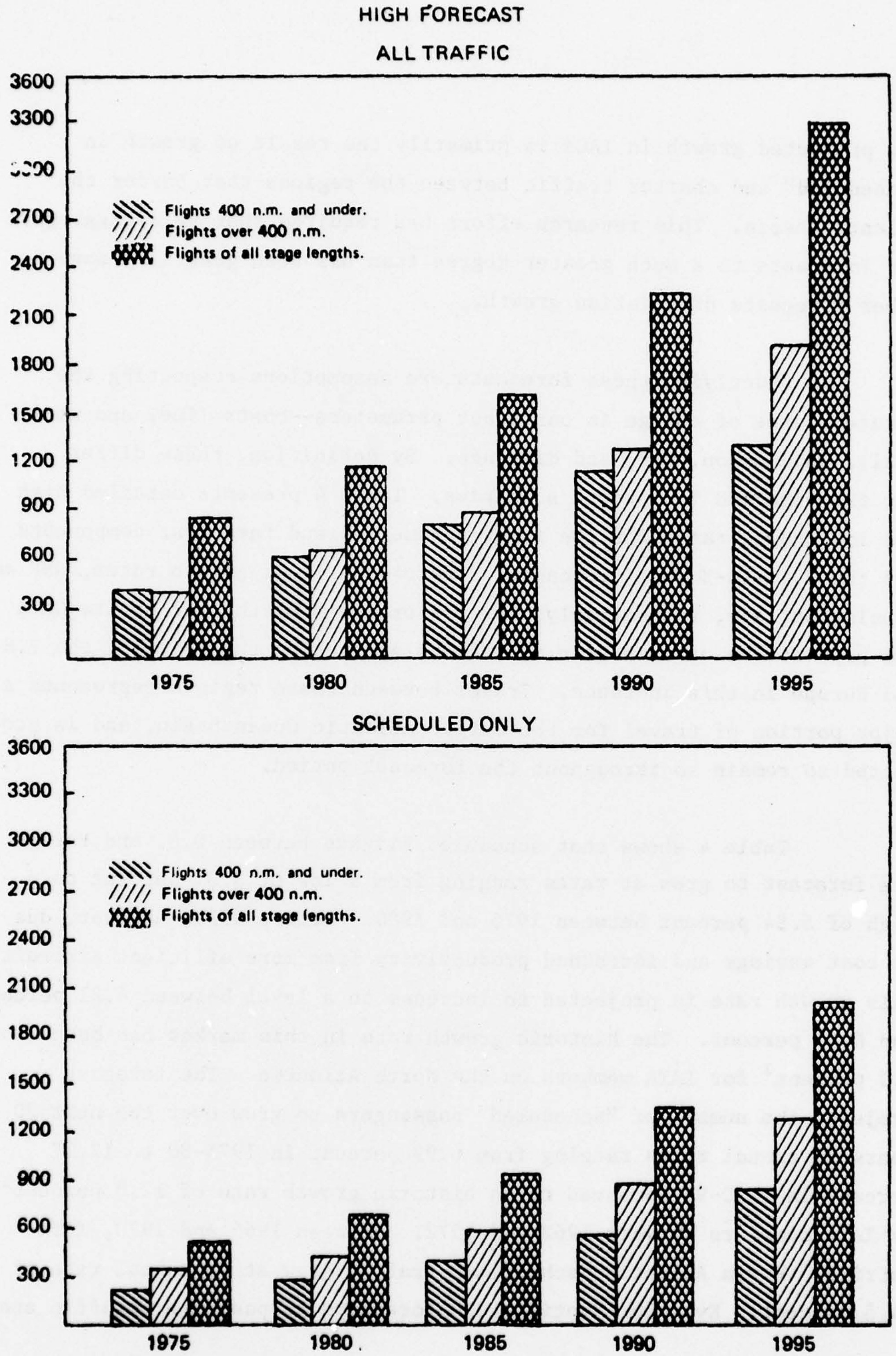
LOW FORECAST

ALL TRAFFIC



Source: Table 3

Figure 1 FORECAST ATLANTIC BASIN IACs FOR 1975, 1980, 1985, 1990, AND 1995



Source: Table 3

Figure 2 FORECAST ATLANTIC BASIN IACs FOR 1975, 1980, 1985, 1990, AND 1995

The projected growth in IACs is primarily the result of growth in "scheduled" and charter traffic between the regions that border the Atlantic basin. This research effort has required that we disaggregate our forecasts to a much greater degree than has been generally done in other forecasts of aviation growth.

Underlying these forecasts are assumptions respecting the future course of change in our input parameters--costs (fuel and non-fuel), population, GNP, and distance. By definition, these differ for the high and low growth scenarios. Table 4 presents detailed high and low growth rates for the input parameters and fare cost components for the U.S.-to-Europe forecasts. Two of the input growth rates, GNP and population, are, respectively, for the products of the per capita GNPs and populations of each pair of regions generating the traffic, the U.S. and Europe in this instance. Travel between these regions represents a major portion of travel for the entire Atlantic Ocean basin, and is projected to remain so throughout the forecast period.

Table 4 shows that scheduled flights between U.S. and Europe are forecast to grow at rates ranging from a low of 3.31 percent to a high of 5.84 percent between 1975 and 1980. Before 1995, however, due to cost savings and increased productivity from more efficient aircraft, this growth rate is projected to increase to a level between 4.21 percent and 8.69 percent. The historic growth rate in this market has been about 7.5 percent[1] for IATA members on the North Atlantic. The forecast projects the number of "scheduled" passengers to grow over the next 20 years at annual rates ranging from 6.99 percent in 1975-80 to 12.37 percent in 1990-95 compared to an historic growth rate of 12.8 percent[1] by IATA carriers between 1962 and 1972. Between 1965 and 1970, IATA carriers' North Atlantic "scheduled" traffic grew at an annual rate of 14.5 percent. Even our "optimistic" forecasts of passenger traffic are

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[1] Calculated from IATA data in World Transport Statistics, pp. 18-19 (1972).

Table 4

SAMPLE PERCENTAGE GROWTH RATE FORECAST: U.S.-TO-EUROPE TRAFFIC

	Low Forecast				High Forecast			
	1980	1985	1990	1995	1980	1985	1990	1995
Forecast growth rates								
PASS AIRCRAFT SIZE	3.09	3.04	2.99	2.99	3.07	3.09	3.00	2.90
NO. OF PASS FLTS (SH)	3.31	3.86	4.21	4.21	5.84	7.27	7.98	8.69
NO. OF PASS FLTS (CH)	10.09	3.86	4.21	4.21	12.80	7.27	7.98	8.69
NO. OF PASS FLTS (GA)	5.19	5.36	5.36	5.36	6.35	6.55	6.55	6.55
NO. OF PASSENGERS	6.99	7.54	7.88	7.88	9.58	11.01	11.69	12.37
PASS LOAD FACTOR	0.59	0.64	0.67	0.67	0.67	0.65	0.71	0.77
COST PER PASS FLT	5.38	4.84	4.31	4.31	4.26	3.17	2.10	1.03
PASS ECON FARE	1.89	1.39	0.90	0.90	0.87	-0.14	-1.13	-2.13
CARGO AIRCRAFT SIZE	3.09	3.04	2.99	2.99	3.07	3.09	3.00	2.90
NO. OF CARGO FLTS	3.31	3.86	4.21	4.21	5.84	7.27	7.98	8.69
Input growth rates								
NONFUEL COSTS	2.00	1.50	1.00	1.00	1.00	0.00	-1.00	-2.00
DISTANCE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
GNP	6.21	6.39	6.39	6.39	7.59	7.81	7.81	7.81
POPULATION	1.62	1.71	1.71	1.71	1.98	2.09	2.09	2.09
FUEL PRICES	2.00	2.00	2.00	2.00	1.00	0.00	0.00	0.00

Note: All growth rates are in percentages on a per annum, compound basis.

SH = Scheduled; CH = Charter; GA = General Aviation

conservative by historical standards. Edward Driscoll, President of the National Air Carrier Association, an organization of charter airlines, recently estimated that the transatlantic market will grow "about 8 percent per year to 1980".[1]

We have forecast all-cargo flights to grow at a rate similar to that of scheduled passenger flights because of similarity between the causal forces affecting passenger and cargo. Boeing[2] forecasts a "total freighter" lift for the world between 1975 and 1985 of about 6 percent. Our high forecasts are that cargo flights should exceed a 7 percent growth rate by 1985 but our low forecasts do not reach 6 percent even by 1990.

There are no long-range general aviation forecasts for the areas studied here. Our forecasts for growth of between 5 and 7 percent per year are conservative in the light of historical patterns. We have forecast no growth for Military Airlift Command (MAC) traffic[3] throughout the period.

2. IACs by Areas and Time of Day

Figure 3 shows the boundaries of the 25 IAC areas used to subdivide the Atlantic basin area and their relation to the true FIR boundaries. The precise location of the IAC areas is shown in Table 5. As noted in the Introduction, in the Atlantic basin analysis and forecasts an attempt was made to relate IAC areas to actual FIRs. The 25

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[1] In Aviation Daily, p. 278 (December 1975).

[2] Interpeted from data in Boeing's Dimensions in Airline Growth, p. 35 (1974).

[3] Movement of military passengers and cargo by civilian airlines under charter.

IAC areas shown on Figure 3 are either approximations (Gander A-2, Shanwick 10-3, Santa Maria A-4) or subdivisions (New York A-10-A-15) or combinations (Africa - IAC A-7 and A-8 and South America IAC A-25). It was found, also noted above, that these areas unduly fragmented major regional and interregional traffic flows and made it difficult to identify the major sources of the traffic contributing to peak area and basin IACs. Therefore, it was necessary for analytical purposes to group the 25 Atlantic IAC areas into subbasins. Analysis of the 1975 data on regional pair contributions to basin and IAC area peak IACs permitted identification of some seven major traffic flows throughout the basin. The subbasins and their component IAC areas are shown on Table 5.

Table 6 shows the 24-hour percentage distribution of flights by Greenwich hours, for the Atlantic basin and its constituent IAC areas. Since these are percentages, they cannot be added to obtain the percentage distribution of diurnal flight activity for the same subbasins. However, when plotted as histograms for each IAC area, the histograms for the IAC areas comprising each subbasin can be superimposed to reveal the IAC peaking characteristics of each subbasin in relation to that for the basin as a whole. The resulting histograms for the Atlantic basin and five of the seven subbasins are shown in Figures 4-7. The New York and Macro Caribbean subbasin contained too many IAC areas for the superimposed histograms to be intelligible. However, histograms for the component IAC areas were drawn so that their combined effect could be demonstrated.

Some caution must be exercised in interpeting these figures. The data in Table 6 used in these histograms are for all traffic[1], including that moving 400 miles or less, and also include continental African and South American traffic. Continental U.S., Canadian and

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[1] The working papers include 24-hour distributions of flight hours by stage length for the base year and the forecast years for each basin and its constituent areas.

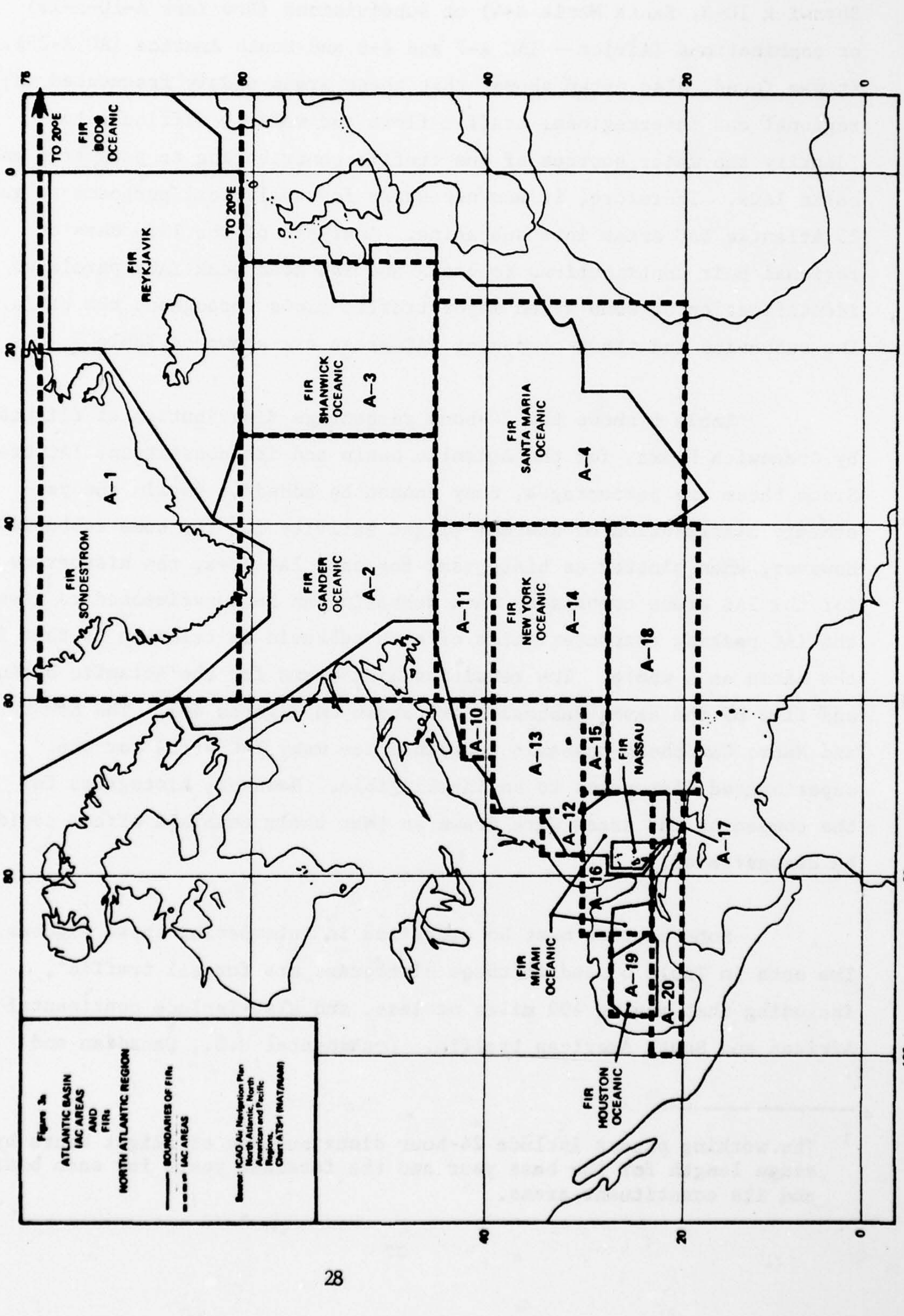

Figure 3a
ATLANTIC BASIN
IAC AREAS
AND
FIRs
NORTH ATLANTIC REGION

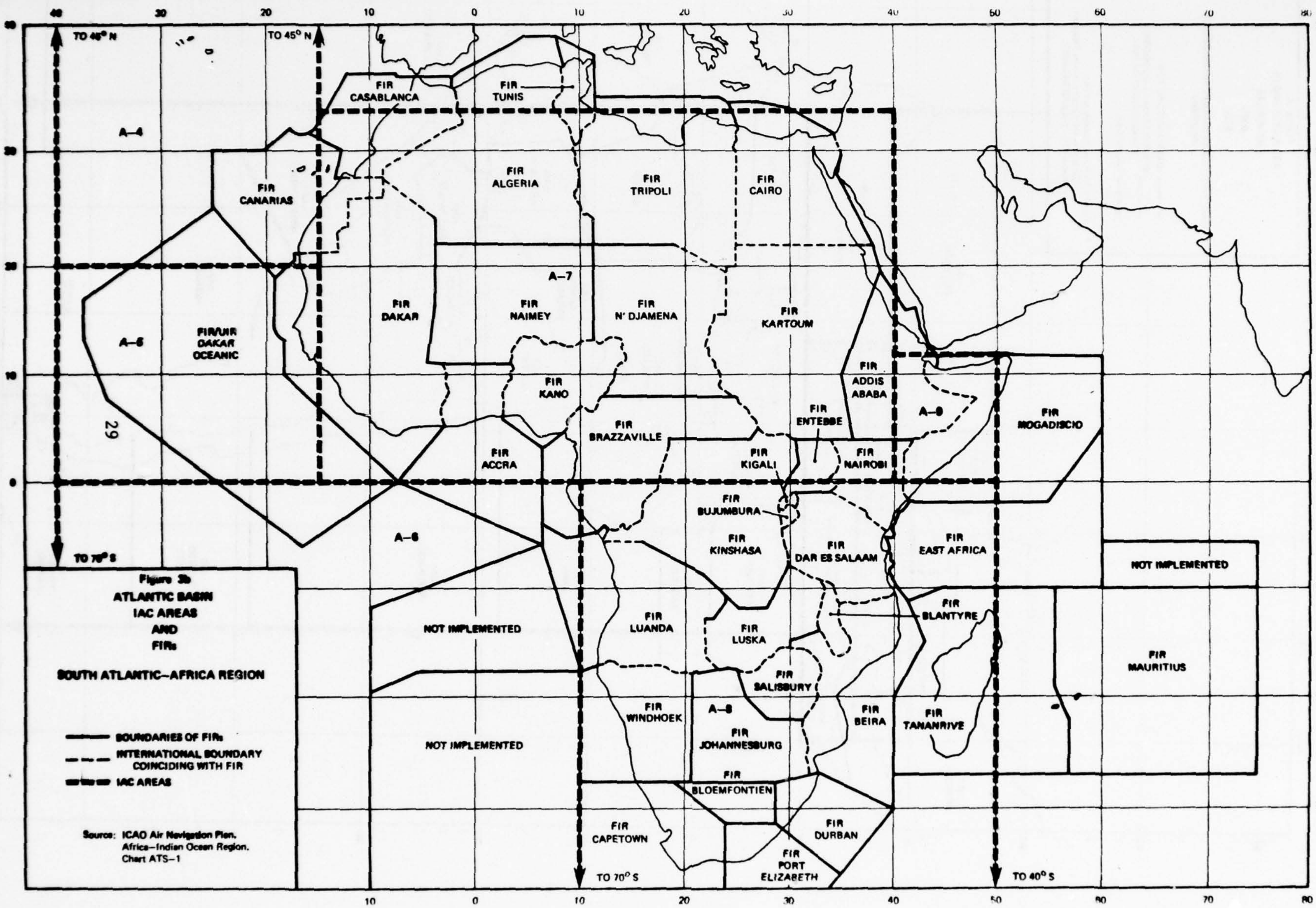

Figure 3b
ATLANTIC BASIN
IAC AREAS
AND
FIRs

SOUTH ATLANTIC–AFRICA REGION

Source: ICAO Air Navigation Plan. Africa–Indian Ocean Region. Chart ATS–1

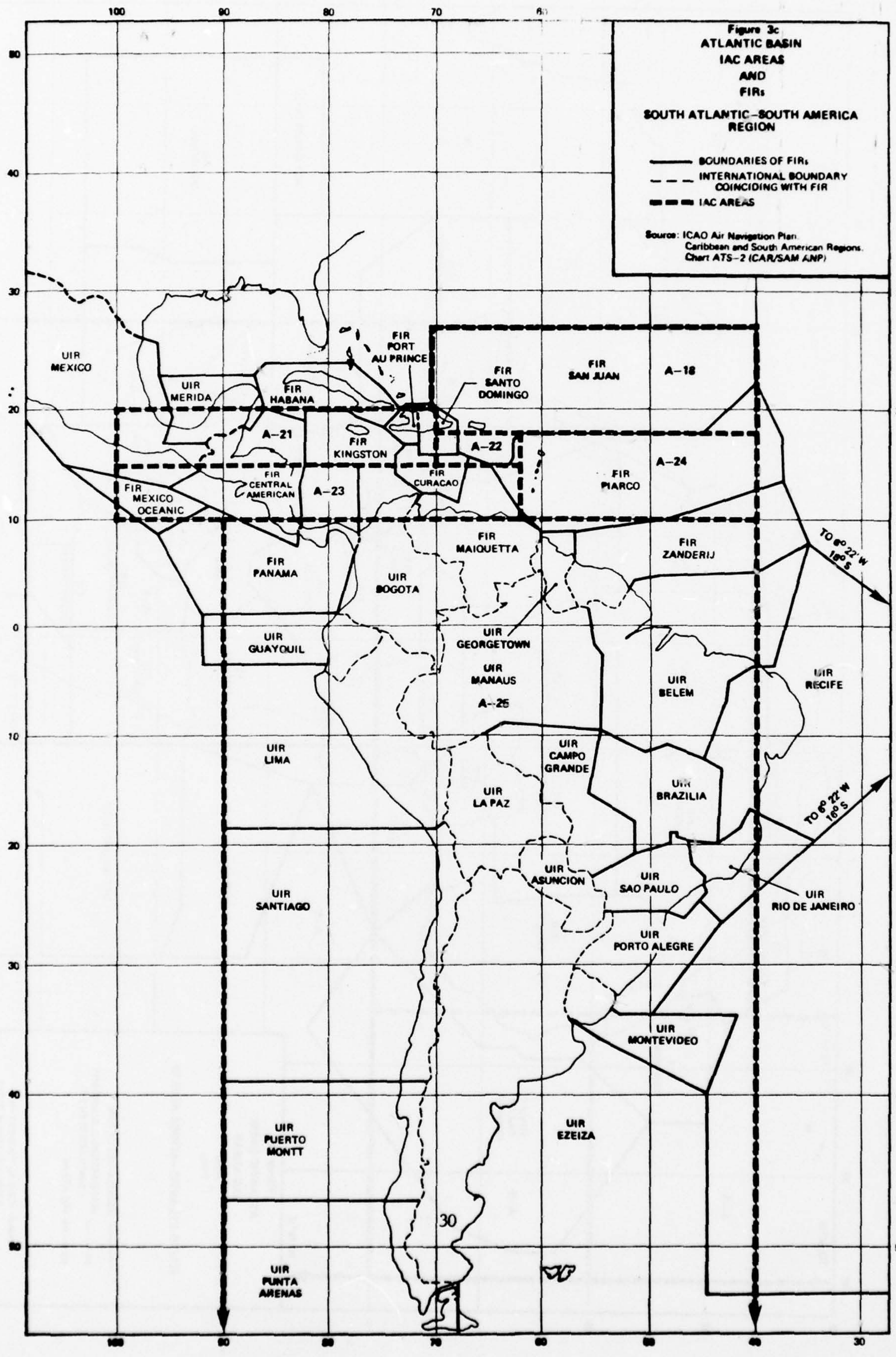

Figure 3c
ATLANTIC BASIN
IAC AREAS
AND
FIRs

SOUTH ATLANTIC–SOUTH AMERICA REGION

BOUNDARIES OF FIRs
INTERNATIONAL BOUNDARY COINCIDING WITH FIR
IAC AREAS

Source: ICAO Air Navigation Plan. Caribbean and South American Regions. Chart ATS–2 (CAR/SAM ANP)

Table 5

IAC AREAS SELECTED FROM REGIONAL AND GEOGRAPHIC AREAS

IAC NUMBER	NORTHEAST LONGITUDE	NORTHEAST LATITUDE	SOUTHWEST LONGITUDE	SOUTHWEST LATITUDE
1	20.0	73.0	-60.0	61.0
2	-30.0	61.0	-60.0	45.0
3	-10.0	61.0	-30.0	45.0
4	-15.0	45.0	-40.0	20.0
5	-15.0	20.0	-40.0	0.0
6	10.0	0.0	-40.0	-70.0
7	40.0	33.0	-15.0	0.0
8	50.0	0.0	10.0	-40.0
9	50.0	12.0	40.0	0.0
10	-60.0	42.0	-67.0	39.0
11	-40.0	45.0	-60.0	39.0
12	-73.0	35.0	-77.0	30.0
13	-60.0	39.0	-73.0	30.0
14	-40.0	39.0	-60.0	27.0
15	-60.0	30.0	-70.0	27.0
16	-70.0	30.0	-87.0	24.0
17	-70.0	24.0	-76.0	20.0
18	-40.0	27.0	-70.0	18.0
19	-87.0	28.0	-96.0	24.0
20	-76.0	24.0	-100.0	20.0
21	-70.0	20.0	-100.0	15.0
22	-62.0	18.0	-70.0	15.0
23	-62.0	15.0	-100.0	10.0
24	-40.0	18.0	-62.0	10.0
25	-40.0	10.0	-90.0	-70.0

Note: These IAC areas correspond to the following regional and geographic designators:

Subbasin	Number	Designator
North Atlantic and Polar Atlantic	A-1	Sondestrom/Reykjavik/Bödo
	A-2	Gander
	A-3	Shanwick
Middle Atlantic	A-4	St. Maria
	A-5	Dakar
South Atlantic	A-6	South Atlantic
Africa	A-7	North Africa
	A-8	South Africa
	A-9	East Africa
New York	A-10-15	New York
Macro Caribbean	A-16-17	Miami
	A-18	San Juan
	A-19	Houston
	A-20-23	Caribbean
	A-24	Piarco
South America	A-25	South America

Table 6

DISTRIBUTION OF FLIGHT HOURS BY GREENWICH HOUR FOR THE ATLANTIC BASIN

Greenwich Hour

SYSTEM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
IAC 1	.028	.029	.029	.028	.028	.028	.027	.025	.024	.026	.033	.044	.055	.063	.065	.068	.061	.060	.055	.054	.050	.045	.041	.034
IAC 2	.002	.027	.078	.080	.032	.035	.047	.029	.029	.016	.021	.040	.063	.077	.057	.057	.093	.123	.071	.023	0.000	0.000	0.000	0.000
IAC 3	.034	.077	.095	.095	.075	.050	.021	.008	.007	.007	.007	.007	.017	.036	.061	.086	.101	.083	.052	.028	.023	.013	.036	.011
IAC 4	.004	.007	.029	.080	.109	.085	.076	.050	.020	.012	.022	.050	.070	.093	.107	.069	.032	.028	.032	.017	.002	.003	.003	.001
IAC 5	.019	.037	.075	.073	.071	.043	.060	.049	.043	.024	.045	.045	.032	.037	.047	.065	.060	.040	.031	.035	.026	.021	.009	.012
IAC 6	.055	.053	.064	.107	.106	.120	.090	.052	.034	.034	.007	.014	.014	.011	.009	.016	.038	.056	.042	.007	.020	.009	.027	.016
IAC 7	.027	.018	.019	.021	.030	.023	.036	.047	.064	.050	.040	.044	.045	.056	.048	.051	.050	.040	.048	.053	.072	.055	.029	.035
IAC 8	.038	.047	.015	.034	.035	.033	.045	.048	.059	.054	.056	.051	.046	.046	.042	.048	.048	.044	.032	.031	.027	.026	.029	.035
IAC 9	.002	.000	.002	.011	.022	.066	.080	.082	.071	.064	.059	.053	.068	.076	.071	.068	.051	.040	.039	.034	.017	.011	.007	.004
IAC 10	.015	.071	.150	.063	0.000	.055	.063	.024	.024	.008	0.000	0.000	.134	.079	0.000	0.000	0.000	.008	0.000	0.000	.024	.150	.131	0.009
IAC 11	.059	.134	.134	.061	0.000	0.000	0.000	0.000	0.000	0.000	.122	0.000	.034	0.000	0.000	0.000	.179	.045	.134	0.000	0.000	0.000	0.000	.069
IAC 12	.081	.087	.104	.037	.034	.021	.021	.006	0.000	.009	.037	.015	.012	.012	.022	.046	.050	.130	.107	.110	.049	.003	.003	.003
IAC 13	.069	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.011	.009	.005	.064	.076	.071	.084	.073	.066	.092	.064	.155	.092	.078
IAC 14	.064	.041	.010	.021	.037	.019	.004	.008	.018	.020	.015	.015	.021	.043	.094	.084	.057	.059	.074	.062	.056	.083	.064	.050
IAC 15	.056	.085	.036	.064	.117	.061	.027	0.000	.025	.026	.024	.005	.005	.049	.091	.057	.030	.049	.064	.015	.011	.032	.006	.066
IAC 16	.059	.041	.010	.020	.024	.037	.014	.010	.019	.037	0.000	.004	.043	.035	.051	.143	.046	.119	.040	.016	.098	.030	.016	.087
IAC 17	.022	.014	.019	.007	.002	.006	.005	.006	.001	.006	.008	.018	.028	.058	.071	.084	.062	.086	.100	.095	.093	.088	.079	.041
IAC 18	.012	.017	.021	0.000	0.000	0.000	.002	.002	0.000	.015	.018	.040	.043	.053	.072	.041	.099	.111	.119	.078	.096	.088	.044	.027
IAC 19	.023	.017	.016	.012	.004	.006	.008	.007	.009	.009	.015	.048	.069	.072	.072	.067	.073	.067	.066	.086	.093	.069	.056	.036
IAC 20	.101	.029	.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.011	.037	.030	.064	.166	.102	.055	[illegible]	.077	.034	.069	.057
IAC 21	.040	.054	.031	.025	.009	.006	.006	.007	.008	.008	.023	.025	.028	.034	.042	.076	.070	.096	.066	.089	.087	.074	.053	.044
IAC 22	.028	.027	.019	.012	.007	.003	.001	.005	.014	.013	.010	.021	.040	.058	.082	.083	.077	.066	.060	.080	.097	.089	.071	.037
IAC 23	.028	.015	.015	.003	.002	0.000	0.000	0.000	.002	.012	.015	.042	.082	.089	.074	.098	.050	.063	.052	.063	.087	.094	.054	.042
IAC 24	.035	.028	.007	.004	.005	.002	.001	.006	.013	.016	.042	.048	.052	.072	.075	.063	.055	.064	.059	.072	.055	.055	.083	.086
IAC 25	.023	.027	.022	.012	.007	.004	.011	.008	.001	.001	.038	.077	.075	.090	.078	.043	.048	.056	.089	.072	.059	.046	.046	.039
	.034	.023	.015	.009	.010	.012	.009	.008	.010	.022	.038	.059	.074	.073	.066	.069	.058	.059	.062	.063	.057	.059	.059	.050

Note: These figures represent the fraction of total daily flight hours that occur each hour of the busy day by area. This case is the base case for all traffic segments of all stage lengths.

European traffic was excluded by definition of the Atlantic basin. But because Africa and Latin America are, to a large extent, dependent on unreliable HF communications systems, and might be interested in taking advantage of an improved navigation/communication system, they were included, and the data in Table 6 therefore include an unexpectedly large number--literally thousands--of daily short-haul interregional flights. In the histogram for the basin activity as a whole, this short-haul traffic partially shadows the long-haul peaking characteristics of areas such as the North Atlantic that has no short-haul traffic.

Inspection of the 1975 and forecast data by IAC areas shown in Appendix D, in APPENDIX I, which does subdivide short- and long-haul traffic, shows that the short-haul traffic is concentrated in IAC areas within or closely adjacent to South America, Africa, and in the Central America/Caribbean areas. This means that there are thousands of daily short-haul aircraft movements now dependent on HF communications that might be candidates for use of an improved COM/NAV system.

Considering these analyses, the following conclusions may be drawn:[1]

The Base Case

- Since the peaks for the individual IAC areas vary widely in time over the Greenwich day, the basin peak created is rather broad as shown for the 1975 base case in Figure 4. For all baseline cases, the peak flight hour for the basin is much higher than any individual subzone

[1] These conclusions are based on interpretation of the peak IAC data for the base and forecast years presented in Appendix D to the APPENDIX I in conjunction with Table 6 and the histograms based on it.

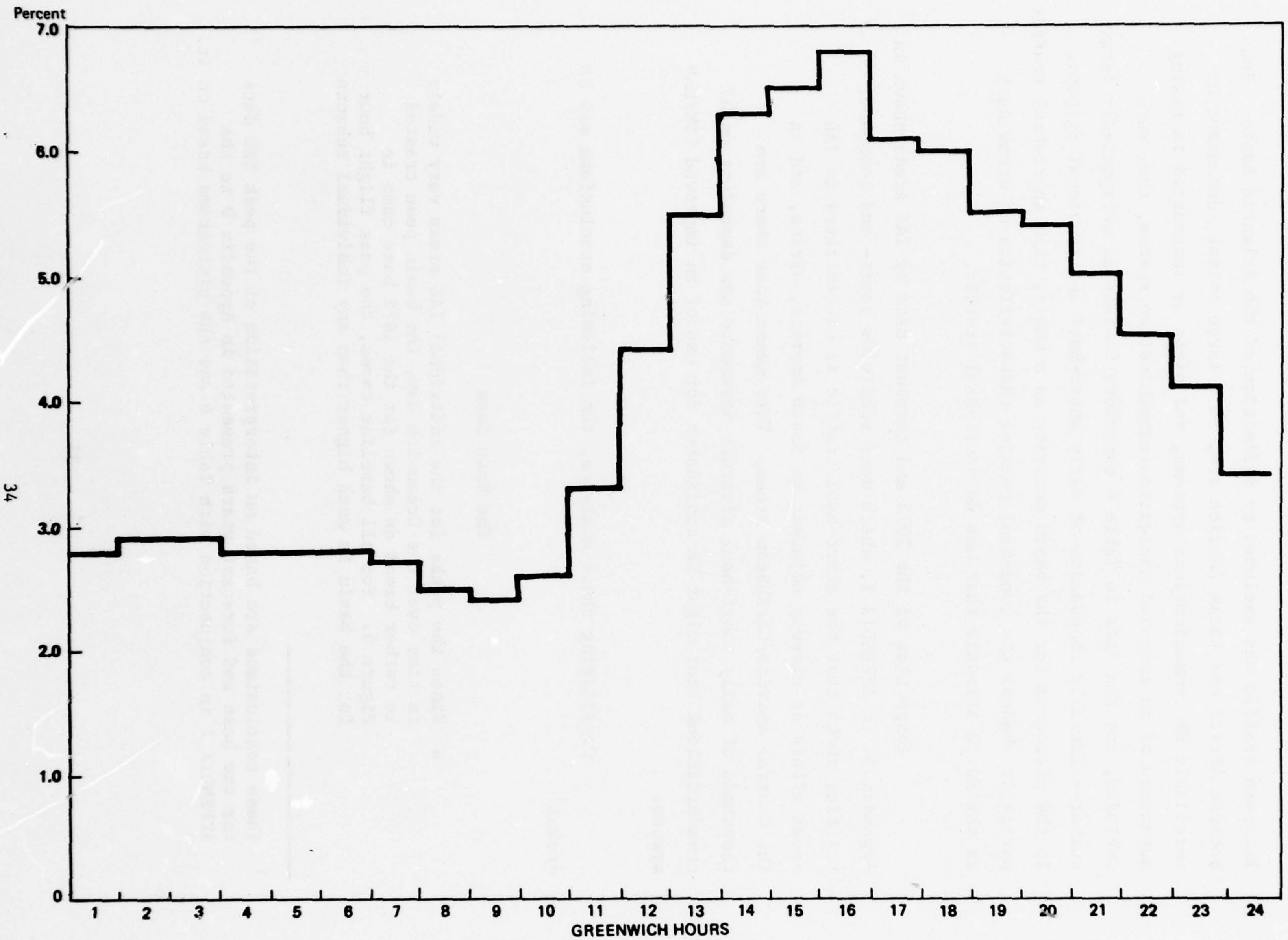

FIGURE 4 PERCENTAGE DISTRIBUTION OF FLIGHT HOURS BY GREENWICH HOUR—1975 BASE CASE ATLANTIC OCEAN BASIN

peak. The basin peak shown in Figure 4 is situated in a four to five hour period of somewhat similar flight hour levels. In general, the basin peak is very nearly the simple sum of individual peaks, indicating the broad contributions of the individual peaks to the total activity.

- The system IAC for "scheduled" long-distance flights (greater than 400 nautical miles) is higher than that for "scheduled" short-distance flights in spite of a substantially higher volume of traffic in the latter category. This effect is eliminated in the "all traffic" cases, but demonstrates that the long-distance "scheduled" traffic is a primary contributor to traffic peaking tendencies in the basin.

- The busy day (the day when the most flights were performed over the basin) was found to be Friday (Greenwich time) during the June-September season.

- The busy flight hour was found to be roughly 1600 GMT for the basin when flights of all lengths were analyzed even when flights of 400 nautical miles or less were included. Activity for shorter flights was found to peak earlier in the Greenwich day, however (around 1400 GMT).

- The busiest subzones appear to be those that correspond to the North Atlantic area of the basin. Because the subzone representations of South America and Africa are geographically large and include intra-area continental traffic, they also display relatively large peak IACs, operations, and entry statistics.

- The North Atlantic IAC areas show a distinct bimodal peaking, as plotted in Figure 5, reflecting the U.S.-Europe and Canada-Europe eastbound and westbound concentrations at different departure and arrival times due to differences in time zones.

- The bimodality is not nearly so pronounced in the Middle Atlantic or South Atlantic IAC areas also shown in Figure 5. IAC area 5 does have a sharp early peak that may reflect Europe-Africa or Intra-Africa traffic movements.

- Except for IAC area 9 that obeys some local behavior pattern of its own, African traffic concentrates in two broad low peaks as shown in Figure 6, in the mid-morning and mid-afternoon (Greenwich time).

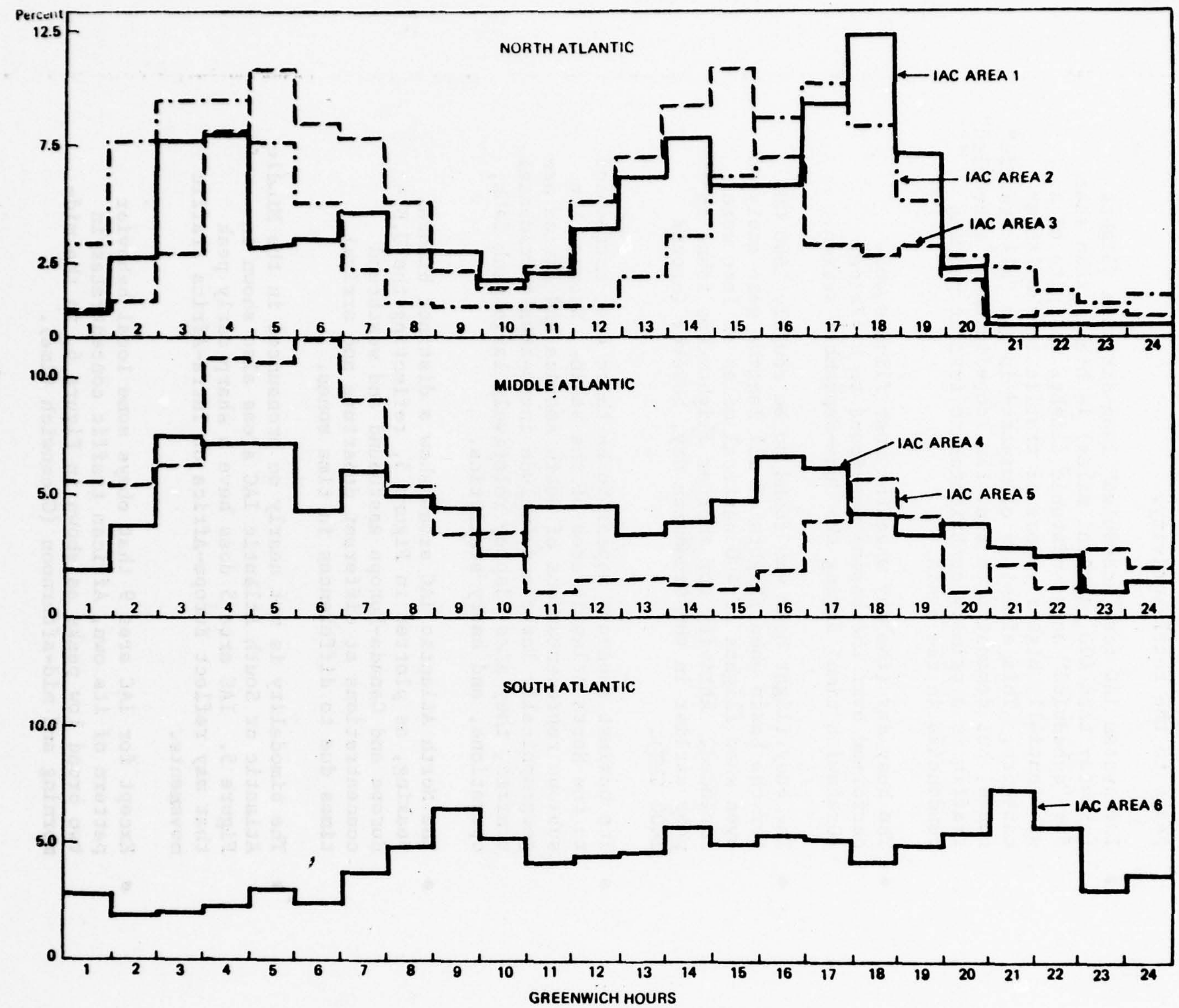

Figure 5 PERCENTAGE DISTRIBUTION OF FLIGHT HOURS BY GREENWICH HOUR–1975 BASE CASE NORTH ATLANTIC, MIDDLE ATLANTIC AND SOUTH ATLANTIC AREAS

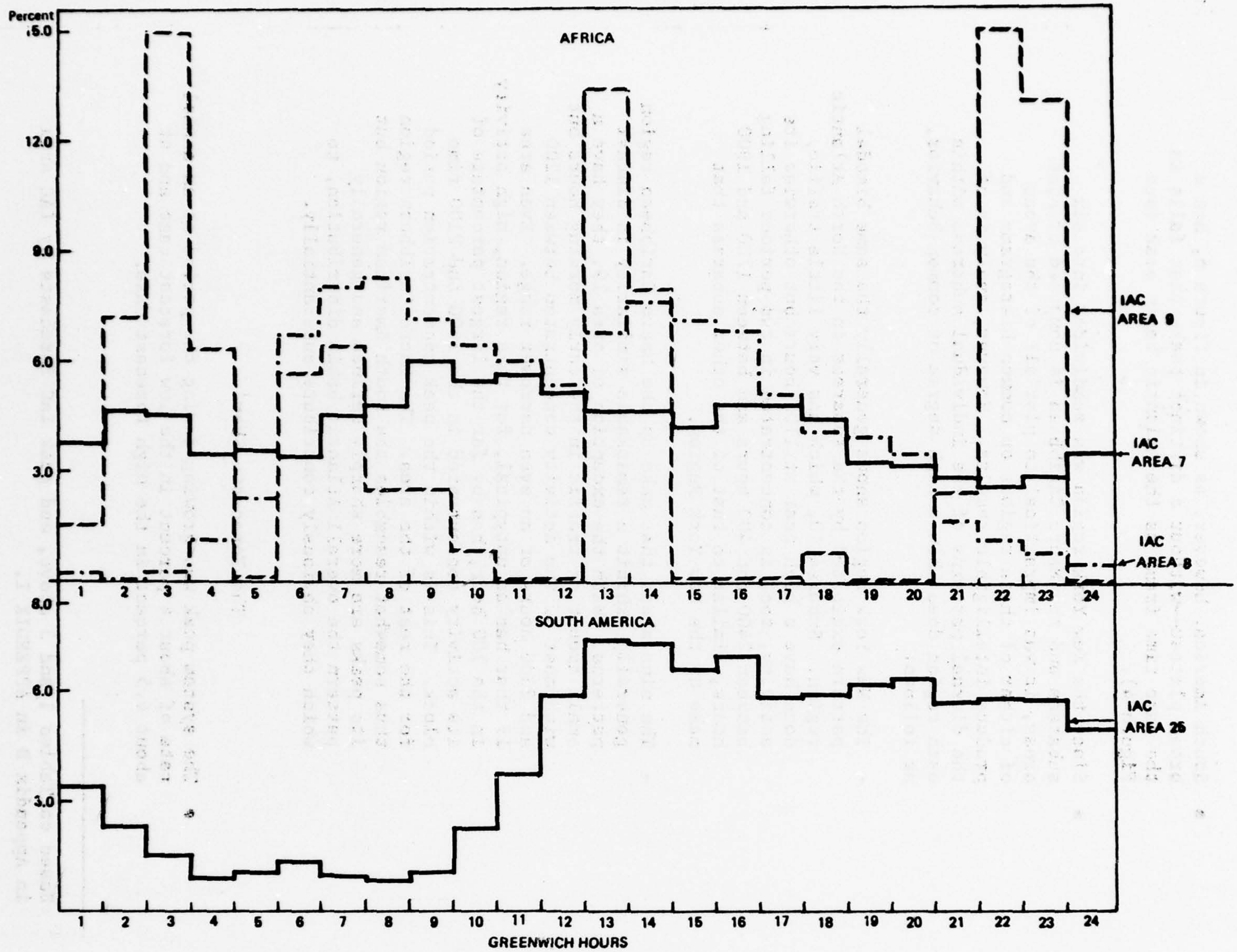

Figure 6 PERCENTAGE DISTRIBUTION OF FLIGHT HOURS BY GREENWICH HOUR–1975 BASE CASE AFRICAN AND SOUTH AMERICAN AREAS

- South America, however, as shown in Figure 6, has a broad plateau--without a distinct peak--that falls in the same time frame as the Atlantic basin peak (see Figure 4).

- Since the New York region was subdivided into six subareas and the Macro Caribbean is composed of nine areas, it was impractical to plot all of the areas of either of these regions on common histograms and produce intelligible results. However, analysis of the diurnal patterns of the individual subareas within each region does show a high degree of common behavior, as follows:

  - The New York region shows generally the same bimodal pattern exhibited by the subareas in the North Atlantic region. Subarea 10, which has very little traffic, does have a high peak at 1100 hours but otherwise its activity, too, is concentrated in two periods falling between 2400 and 400 hours and between 1700 and 1900 hours, similar to that of the other subareas that make up the New York Region.

  - The nine areas that make up the Macro Caribbean region generally exhibit a remarkable similarity in diurnal patterns. With the exception of area 19, they have a small amount of traffic in the early morning hours but with most of the activity concentrated between 1200 and 2300 hours or an even narrower range. Even area 19 that has an untypical, for this region, high activity in the 100 hour, has by far the largest percentage of its activity concentrated in the 1600 and 2100 time block. This is within the peak concentration period for the rest of the area. The Macro Caribbean region thus somewhat resembles the South American region but its peaks are more sharply defined and generally pattern the overall Atlantic basin distribution, to which they obviously contribute substantially.

The Forecasts Show[1]

- The system peak was growing during the period at an annual rate of about 4 percent in the low forecast case and at about 6.5 percent in the high forecast case.

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[1] Based on Tables 1 and 3 above, and peak IAC forecasts by IAC area in Appendix D in APPENDIX I.

- The broadness of the system peak remained a significant characteristic of the traffic statistics. Individual IAC area peaks continued to be sharper and, by and large, remained in the same point in time.

- Minor shifts occurred in the relative levels of activity in the constituent IAC areas, but none of the projections indicates that the relative dominance of North Atlantic IAC areas, observed in the baseline runs, is likely to be altered in the future.

- In spite of relatively disparate rates of growth in the interregional traffic segments that contribute to the basin activity, the temporal and spatial peaking characteristics of projected traffic are similar to those discerned for baseline traffic: the busy day of the season remained Greenwich Friday; the busy flight hour for the basin remained 1600 GMT for all flights and flights greater than 400 nautical miles, and 1400 GMT for all flights less than 400 nautical miles.

3. Composition of Atlantic Ocean Basin Activity

Appendix E in APPENDIX I shows the region and interregional pair contributions to the peak IACs for the Atlantic basin and its constituent IAC areas. Analysis of Appendix E shows that:

North Atlantic traffic is primarily traffic moving between Europe and the U.S. and Canada plus some traffic between the Caribbean and Europe.

Middle Atlantic traffic is derived from U.S.-African, European-African, some Canadian and U.S. and Caribbean-European traffic, South American-European traffic and South American-African traffic together with considerable short-haul intra-African traffic.

South Atlantic traffic is primarily intra-African and intra-South American traffic, together with European-African and European-South American traffic as well as South American-African traffic.

African traffic is predominantly short-haul intra-African traffic and European-African traffic, with small amounts of South American-European and South American-African as well as some U.S.-African traffic.

New York traffic includes some United States and Canadian -European traffic and U.S.-African traffic. Caribbean-European traffic moves through the New York area. The other major traffic flows between the U.S. and Central America, the Caribbean and South America.

Macro Caribbean includes a large amount of intra-area short-haul traffic: intra-Central American, intra-Caribbean, and some intra-South American traffic. Considerable Canadian and U.S.-Caribbean, and U.S.-South American traffic moves through the area together with some South American-European and South American-African traffic.

South American traffic is mainly local intra-South American traffic (much of it short haul), together with South American traffic to the U.S., Europe, and Africa, and to Central America and the Caribbean. Since IAC area 25 also includes Panama, there is also some intra-Central American and Central American-U.S. traffic.

C. Findings: Indian Ocean Basin

The level of aviation activity in the Indian Ocean basin is influenced by the interaction of several major world regions, including Europe, Africa, the Middle East, the Far East, and Australasia/Oceania. North America indirectly influences this basin activity through the Atlantic and Pacific basins more than it does directly. The basic economic model employed in this research forecasts the rate of growth of interregional and intraregional activity in markets that are relevant to the Indian basin. This chapter describes the outcome of this forecasting process including the effect of traffic and its growth on the peak IACs observed over the Indian Ocean basin.

The section is divided into three parts:

- Base and forecasted (high/low) Indian Ocean basin IACs by stage length
- IACs by IAC areas and time of day
- Composition of Indian Ocean basin activity

1. Base and Forecasted (high/low) Indian Ocean Basin IACs by Stage Length

The conversion of interregional air traffic forecasts to peak instantaneous airborne counts proceeded as in the Atlantic basin analysis. The region pairs that were potential contributors to activity over the basin were identified and only those flights which were identified with those region pairs were permitted to enter into the total basin flight count.[1] Also, this subset of flights is used to calculate the basin busy day.

The September 1975 version of the OAG tape was used throughout the Indian Ocean basin analysis to maintain comparability with the Atlantic basin analysis. The issue of whether September (actually, late summer and fall) schedules are a representation of the busiest season was difficult to resolve for this basin. Air India's traffic, for example, appears to peak in September (in terms of passengers carried) while Thai International's traffic peaks in August. The traffic on Quantas Airlines peaks earlier in the year while that on Singapore Airlines peaks in the fall.[1]

Therefore, the definition of a seasonal basin peak was somewhat ambiguous and September was selected as a month representing a period that was a reasonable compromise. The processing of the September tape revealed that the peak day was (Greenwich) Friday for the Indian basin.

Table 7 presents a high and low forecast, based respectively on optimistic and pessimistic assumptions for the years 1985 and 1995. Both high and low forecasts are presented for "scheduled only" and

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[1] According to ICAO carrier statistics from the period.

Table 7

FORECAST INDIAN BASIN PEAK IACS FOR 1975, 1985, AND 1995

Case		Based on 10 IAC Areas		
	1975		1985	1995
	Flights of All Stage Lengths			
All Traffic	234(6)	(HI)	525(6)	1269(6)
		(LO)	386(6)	624(6)
Scheduled Only	226(6)	(HI)	508(6)	1208(6)
		(LO)	371(6)	592(6)
	Flights of 400 Nautical Miles or Less			
All Traffic	99(6)	(HI)	220(6)	518(6)
		(LO)	162(6)	257(6)
Scheduled Only	96(6)	(HI)	214(6)	503(6)
		(LO)	156(6)	247(6)
	Flights of Longer Than 400 Nautical Miles			
All Traffic	133(7)	(HI)	297(7)	751(6)
		(LO)	219(7)	367(6)
Scheduled Only	128(7)	(HI)	287(7)	704(6)
		(LO)	210(7)	345(6)

NOTE: These data were derived using the late summer and fall season Reuben H. Donnelley Official Airline Guide (OAG) data base for 1975 and interregional traffic forecasts from SRI. The busy day in all cases was Greenwich Friday. The busy flight hour in Greenwich time is given in parentheses after each IAC estimate.

"all traffic", respectively, and for flights of "all stage lengths", "400 nautical miles or less", and "longer than 400 nautical miles".

"Scheduled only" traffic consists of scheduled passenger and cargo traffic and is forecast from the data base embodied in the OAG statistics and ICAO. "All traffic" includes nonscheduled and general aviation traffic. The reader should recognize that this additional increment of traffic was calculated from models of this activity rather than from actual observations; the base case and forecasts in the "all traffic" category are thus much less reliable than the "scheduled only" data and should be used accordingly.

The busy hour of the busy day (Friday) was found to be 0600 Greenwich Mean Time. Table 7 shows that it is estimated that there were 234 "all traffic" flights of all stage lengths over the Indian Ocean basin during that hour. Of these, 226 were "scheduled" flights. Ninety-nine flights were 400 nautical miles or less of which 96 were "scheduled only". For flights over 400 nautical miles it was found that the busy hour for the busy day in 1975 for the Indian Ocean basin was 0700 Greenwich Mean Time. During this busy hour there were 133 flights over 400 nautical miles of which 128 were "scheduled".

For "scheduled only" and all stage length traffic, Table 7 shows that the peak instantaneous airborne count of flights in the busy hour of the busy day is projected to increase from 226 in 1975 to 1,208 in 1995 under the optimistic (high) forecast, for an annual growth rate of approximately 8.7 percent. In the low (pessimistic) case, it is projected that traffic will grow from 226 to 592 peak instantaneous airborne flights by 1995, for an annual growth rate of approximately 4.9 percent.

"Scheduled" flights over 400 nautical miles are expected to grow somewhat faster. In the optimistic assumption they are projected to grow from 128 during the peak hour in 1975 to 704 by 1995, for an

approximate annual growth of 8.9 percent, and in the low assumption from 128 in 1975 to 345 in 1995, for an approximate annual growth of 5.1 percent. The "all traffic" growth patterns follow the same general trend with the traffic for flights of all stage lengths growing from 234 estimated for 1975 to 1,269 in the high forecast and 624 in the low forecast by 1995, representing growth rates of 8.8 and 5.5 percent respectively.

It is interesting to note that, while the peak hour of the busy day was 0600 Greenwich for flights of all stage lengths and for flights of 400 nautical miles or less and remains 0600 Greenwich throughout the forecast period of 1985 and 1995, it was 0700 Greenwich Mean Time in 1975 for flights longer than 400 nautical miles. While it remained 0700 Greenwich for the 1985 forecast year, it shifted to 0600 Greenwich by the 1995 forecast year. This is apparently due to the difference in growth rate forecasts for particular flight segments.

The divergence in rates of growth between the high and low forecasts causes about a difference factor of two between the optimistic and pessimistic assumption over a 20-year period. The fact that the "all traffic" case performed similarly to the "scheduled only" case indicates that the nonscheduled component of traffic in the Indian Ocean basin remains small during the period because of its small initial share in spite of the assumption of rapid growth.

Table 1, above, comparing the projected growth rates for all stage lengths, types of traffic and both forecast scenarios for the three ocean basins, shows that by any measure the Indian basin is projected to grow faster than the Atlantic and Pacific basins.

This holds for both growth scenarios, for "all traffic" as well as "scheduled", and for all stage lengths, short- and long-haul and combined. However, within the Indian basin the long-haul (over 400 n.m.) traffic is projected to grow faster than the short-haul (400 n.m. and under). This is brought out clearly by Figures 7 and 8 that are derived from Table 7. Figure 7 is based on the "pessimistic" or low forecast and Figure 8 on the "optimistic" or high forecast. Of course, the data for 1975 are the same for Figures 7 and 8, there being no high and low estimates for 1975. These figures show the estimated growth in short- and long-haul traffic and in traffic of all stage lengths, separately for "scheduled" and for "all traffic", for each forecast scenario. Both Figures 7 and 8 demonstrate clearly that long-haul traffic (over 400 n.m.) is projected to grow faster than short-haul traffic throughout the full range of forecasts.

2. IACs by IAC Area and Time of Day

As we noted above, the Indian and Pacific Ocean basins were subdivided into rectangles, called IAC areas, that respected the patterns of traffic flow anticipated in the basin rather than attempting to approximate FIRs as was done in the Atlantic. For example, Indian IAC area I-1 is bounded by lines running through the airports serving Hong Kong, Bangkok and Singapore; I-4 embraces India, Burma, Malaysia and much of Pakistan; I-5 includes Iran, Saudi Arabia and most of the Middle East. The map of the entire area, Figure 9, shows the boundaries of the Indian basin IAC areas and their relation to FIRs. The precise description of the Indian IAC areas is shown on Table 8.

Table 9 presents a base year representation of peak IACs by IAC area. Calculations are presented for 1975[1] scheduled traffic for flights of all lengths, stage lengths 400 nautical miles and less,

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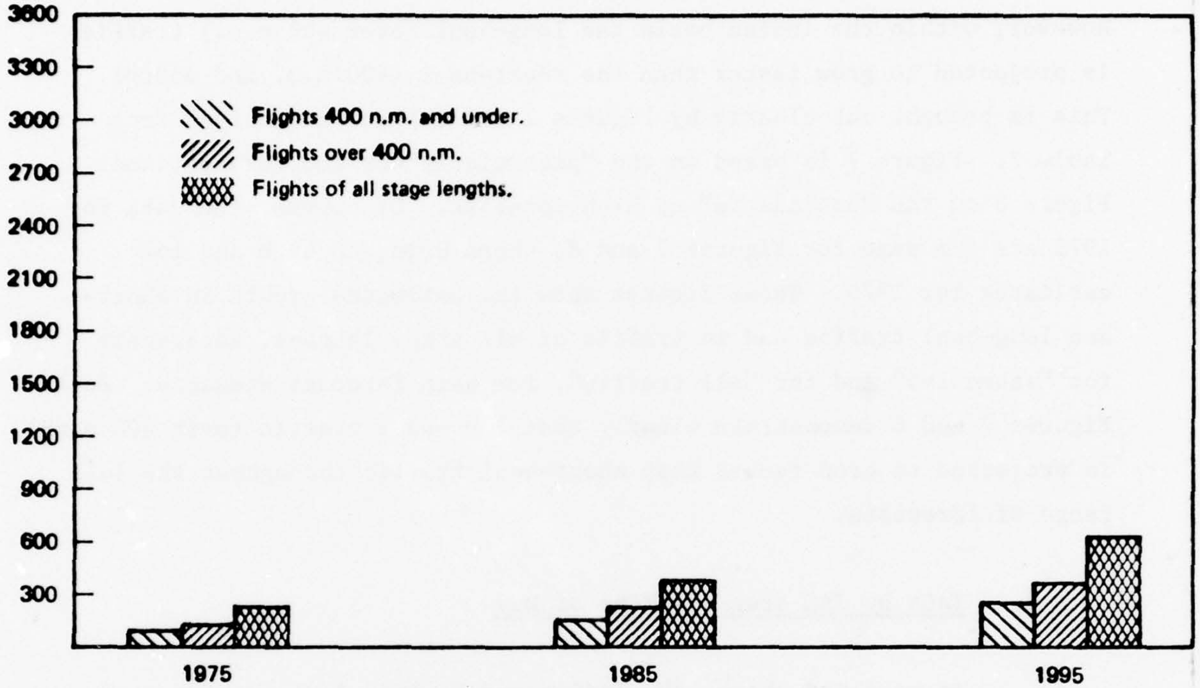
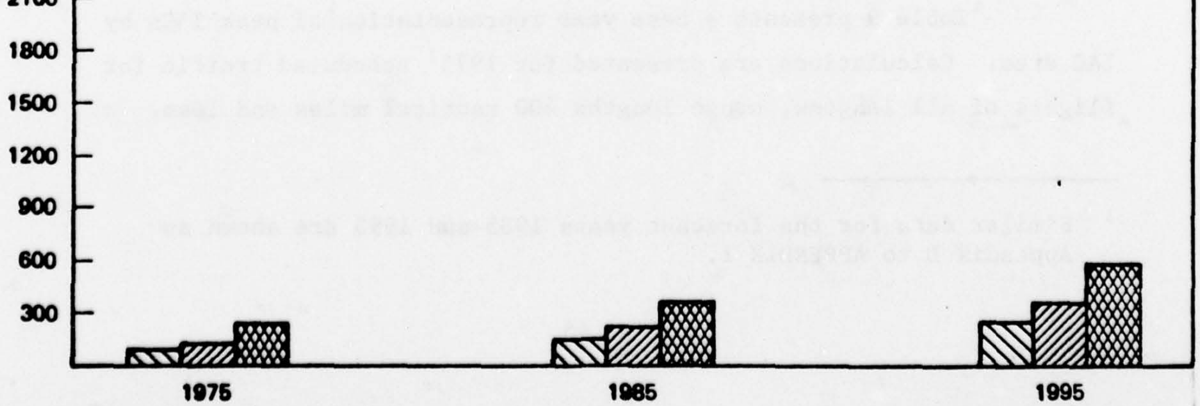
[1] Similar data for the forecast years 1985 and 1995 are shown as Appendix D to APPENDIX I.

LOW FORECAST
ALL TRAFFIC



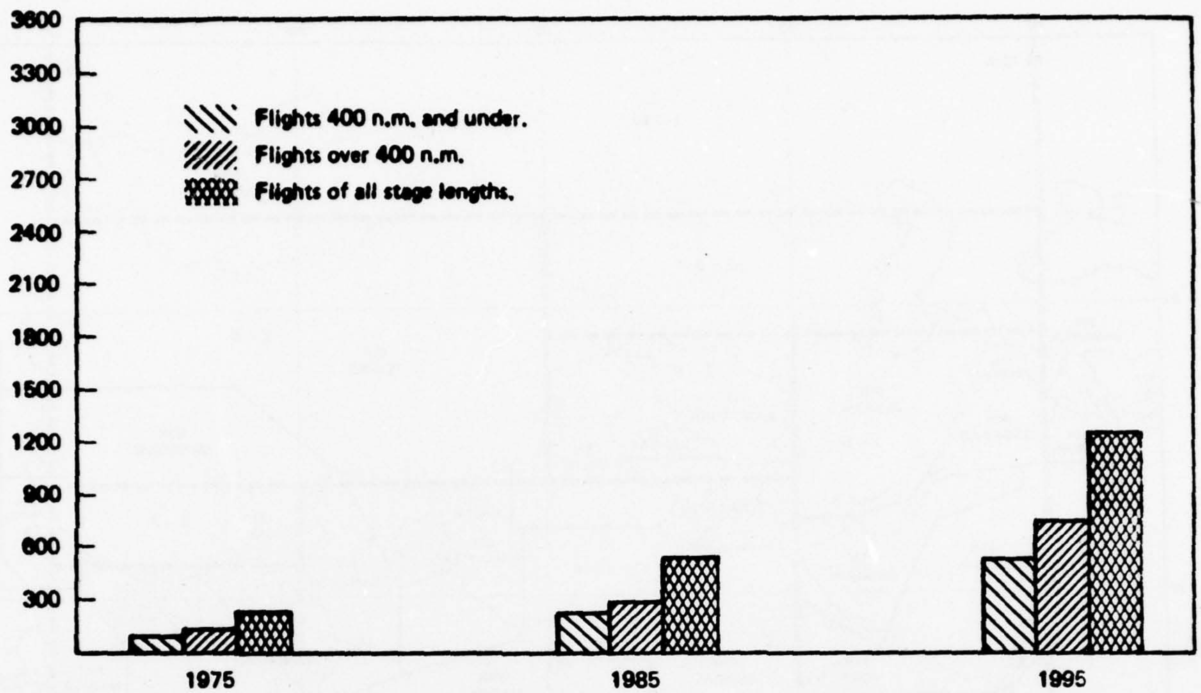
SCHEDULED ONLY



Source: Table 7

Figure 7 FORECAST INDIAN BASIN IACs FOR 1975, 1985 AND 1995

HIGH FORECAST
ALL TRAFFIC



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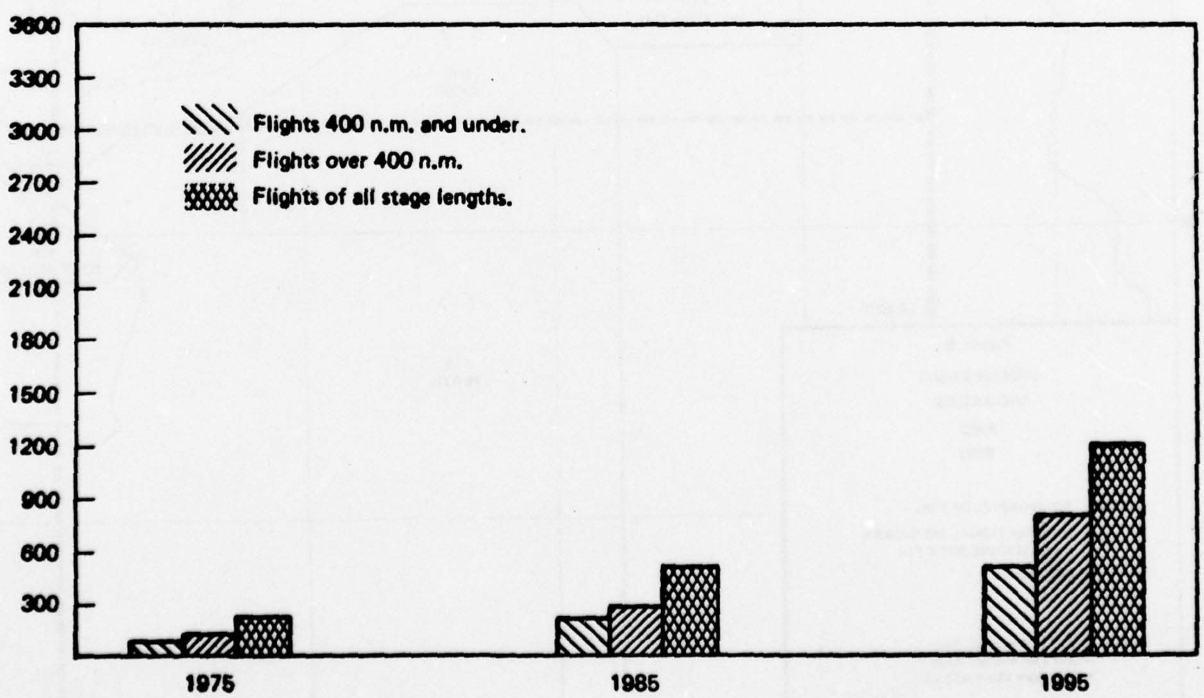

Source: Table 7

Figure 8 FORECAST INDIAN BASIN IACs FOR 1975, 1985 AND 1995

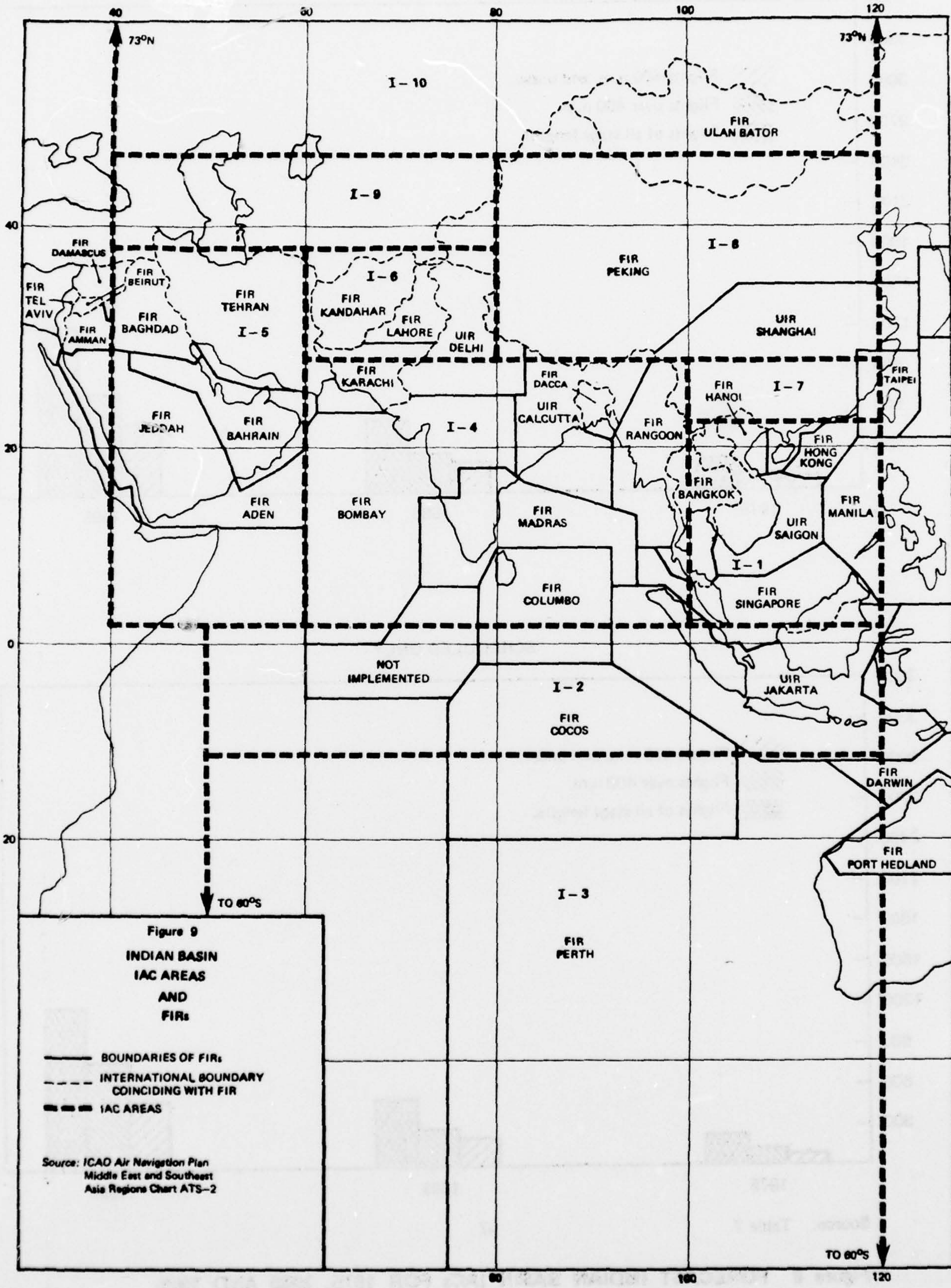
I – 10
FIR ULAN BATOR
I – 9
I – 8
FIR PEKING
FIR DAMASCUS
FIR BEIRUT
FIR TEL AVIV
FIR AMMAN
FIR BAGHDAD
FIR TEHRAN
I – 5
I – 6
FIR KANDAHAR
FIR LAHORE
UIR DELHI
UIR SHANGHAI
FIR KARACHI
FIR DACCA
UIR CALCUTTA
FIR HANOI
I – 7
FIR TAIPEI
FIR JEDDAH
FIR BAHRAIN
I – 4
FIR RANGOON
FIR HONG KONG
FIR BANGKOK
FIR ADEN
FIR BOMBAY
FIR MADRAS
UIR SAIGON
FIR MANILA
I – 1
FIR COLUMBO
FIR SINGAPORE
NOT IMPLEMENTED
I – 2
FIR COCOS
UIR JAKARTA
FIR DARWIN
FIR PORT HEDLAND
I – 3
FIR PERTH
TO 60°S
73°N
Figure 9
INDIAN BASIN
IAC AREAS
AND
FIRs
BOUNDARIES OF FIRs
INTERNATIONAL BOUNDARY COINCIDING WITH FIR
IAC AREAS
Source: ICAO Air Navigation Plan Middle East and Southeast Asia Regions Chart ATS–2

Table 8

LOCATION OF INDIAN BASIN IAC AREAS

IAC Area	NE Longitude	NE Latitude	SW Longitude	SW Latitude
I-1	120.0	22.3	100.6	1.4
I-2	120.0	1.4	50.0	-12.0
I-3	120.0	-12.0	50.0	-50.0
I-4	100.6	28.6	60.0	1.4
I-5	60.0	38.0	40.0	1.4
I-6	80.0	38.0	60.0	28.6
I-7	120.0	28.6	100.6	22.3
I-8	120.0	45.0	80.0	28.6
I-9	80.0	45.0	40.0	38.0
I-10	120.0	73.0	40.0	45.0

Indian Basin

IAC Area	Major Location(s) Included in Area
I-1	Hong Kong/Singapore/Thailand
I-2	Indonesia
I-3	Southern Indian Ocean
I-4	India
I-5	Middle East
I-6	Afghanistan
I-7	Canton P.R.C.
I-8	People's Republic of China
I-9	South Central U.S.S.R.
I-10	Siberia (U.S.S.R.)

Table 9

PEAK IAC CALCULATIONS BY IAC AREA FOR THE INDIAN OCEAN BASIN:
1975 SCHEDULED TRAFFIC ONLY

	Busy Entry Hr	Entries	Busy OPS Hr	OPS	Busy Flite Hr	Fhrs	IAC For Busy Fhr
Flights of All Stage Lengths							
Basin	5.	167.0	5.	159.5	6.	205.1	226.0
IAC I-1	4.	52.0	4.	43.5	6.	54.7	58.0
IAC I-2	2.	26.0	4.	27.0	7.	27.8	31.0
IAC I-3	4.	10.0	4.	10.5	16.	9.8	12.0
IAC I-4	3.	53.0	3.	52.5	3.	64.7	71.0
IAC I-5	5.	32.0	7.	32.0	7.	30.9	35.0
IAC I-6	6.	11.0	5.	9.0	6.	8.2	12.0
IAC I-7	5.	14.0	7.	12.5	6.	14.4	16.0
IAC I-8	1.	7.0	2.	4.5	2.	8.1	9.0
IAC I-9	3.	18.0	3.	14.0	4.	13.2	16.0
IAC I-10	4.	8.0	7.	7.5	7.	16.1	19.0
Flights of 400 Nautical Miles or Less							
Basin	4.	107.0	4.	101.0	6.	88.0	96.0
IAC I-1	1.	39.0	2.	35.5	6.	24.9	27.0
IAC I-2	1.	17.0	2.	18.0	3.	15.6	17.0
IAC I-3	2.	5.0	2.	4.5	7.	2.4	3.0
IAC I-4	3.	36.0	5.	37.0	3.	32.4	37.0
IAC I-5	6.	18.0	6.	19.5	7.	14.1	17.0
IAC I-6	5.	8.0	5.	6.5	7.	5.1	7.0
IAC I-7	2.	5.0	2.	4.5	6.	2.5	3.0
IAC I-8	1.	4.0	1.	2.0	2.	3.9	5.0
IAC I-9	6.	3.0	6.	2.5	1.	1.9	2.0
IAC I-10	2.	1.0	2.	.5	3.	1.0	1.0
Flights Longer than 400 Nautical Miles							
Basin	6.	68.0	5.	58.5	7.	119.7	128.0
IAC I-1	4.	21.0	4.	17.0	6.	29.8	31.0
IAC I-2	4.	14.0	4.	13.0	10.	16.9	19.0
IAC I-3	4.	9.0	4.	9.0	16.	9.8	12.0
IAC I-4	1.	18.0	7.	17.0	3.	32.3	35.0
IAC I-5	22.	19.0	22.	15.5	24.	22.1	24.0
IAC I-6	22.	7.0	22.	7.5	22.	6.1	7.0
IAC I-7	6.	12.0	6.	10.5	6.	11.9	14.0
IAC I-8	2.	4.0	2.	3.0	14.	5.1	6.0
IAC I-9	3.	16.0	3.	13.0	3.	11.4	14.0
IAC I-10	4.	8.0	7.	7.0	7.	15.5	18.0

and stage lengths over 400 nautical miles. While the 10 IAC areas used to subdivide the Indian Ocean basin are not of equal area (and thus the peak IACs are not perfectly comparable), it is important to note that IAC areas I-1 and I-4 reveal the highest peak IACs and IAC areas I-2 and I-5 are the next highest, whether we consider all stage lengths, those 400 nautical miles or less or those over 400 nautical miles. These IAC areas are over the busy Southeast Asian area that includes Hong Kong, Bangkok and Singapore (I-1), and Indonesia (I-2), India and other major generators of aviation activity (I-4), and over the Middle East (I-5). IAC areas I-7, I-8, and I-9, on the other hand, are situated over the predominantly Communist regions in Central and Far Eastern Asia where the activity is less well known, overflights are somwhat restricted, and international operations are probably lower than in the more active areas. IAC area I-3, which is over the Southern Indian Ocean, and I-6, which is over Afghanistan, northern Pakistan and the Kashmir, also show low activity. However, IAC area I-10, that includes the USSR overflight traffic, shows somewhat higher activity.

The entire Indian Ocean basin, while a very large area in total, experiences a peak IAC of only 226 while the Atlantic basin peak IAC was 516 and that for the Pacific basin was roughly 306.

Table 10 presents for the base year 1975[1]--for "scheduled" traffic of all stage lengths--a distribution of flight hours by Greenwich hour for the Indian Ocean basin. These data represent the fraction of the total daily flight hours that occur in each hour of the busy day by IAC area. The same data are represented in graphic form in the histograms presented in Figures 10 through 20. Examination of these histograms in conjunction with Table 7 provides further understanding of the peaking characteristics of the Indian Ocean basin as a whole and of particular IAC areas:

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1 Similar data for the forecast years 1985 and 1995 are available in the Working Papers.

Table 10

DISTRIBUTION OF FLIGHT HOURS BY GREENWICH HOUR FOR THE INDIAN OCEAN BASIN
(1975 scheduled traffic only-all stage lengths)

Greenwich Hour

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Basin	.046	.058	.063	.061	.062	.068	.067	.060	.058	.054	.048	.039	.038	.034	.030	.026	.023	.021	.022	.022	.020	.023	.023	.029
IAC I-1	.056	.069	.066	.074	.082	.092	.080	.087	.081	.065	.057	.043	.041	.033	.021	.013	.005	.001	.002	.003	.002	.001	.002	.023
IAC I-2	.064	.073	.078	.068	.079	.065	.085	.062	.073	.068	.063	.048	.047	.031	.030	.017	.006	.0000	.0000	.0000	.0000	.000	.005	.039
IAC I-3	.046	.032	.043	.073	.043	.050	.056	.053	.044	.042	.034	.050	.034	.055	.083	.115	.067	.015	.015	.009	.0010	.000	.008	.028
IAC I-4	.040	.069	.080	.074	.064	.062	.058	.056	.050	.050	.046	.035	.034	.031	.029	.026	.029	.029	.027	.024	.024	.025	.022	.015
IAC I-5	.039	.033	.038	.039	.047	.057	.063	.048	.041	.042	.039	.034	.030	.030	.037	.039	.041	.045	.044	.048	.032	.046	.040	.047
IAC I-6	.016	.017	.048	.055	.052	.080	.073	.060	.060	.033	.043	.037	.045	.029	.029	.011	.021	.017	.026	.037	.058	.059	.052	.042
IAC I-7	.050	.059	.067	.079	.076	.132	.108	.078	.078	.073	.065	.025	.044	.037	.007	.003	.0010	.0000	.0000	.0000	.0000	.000	.007	.014
IAC I-8	.073	.151	.128	.030	.015	.009	.026	.056	.058	.063	.034	.067	.073	.095	.045	.025	.019	.0060	.000	.017	.0070	.0000	.000	.002
IAC I-9	.056	.049	.065	.068	.048	.042	.048	.033	.043	.059	.042	.042	.030	.037	.032	.034	.027	.025	.024	.022	.048	.042	.045	.040
IAC I-10	.050	.040	.029	.015	.036	.062	.064	.052	.052	.047	.039	.041	.046	.035	.030	.026	.027	.039	.053	.049	.037	.046	.046	.040

NOTE: These figures represent the fraction of total daily flight hours that occur each hour of the busy day by IAC area.

The Base Case

- Although the peak for the Indian Ocean basin is, as we have noted, considerably lower than that for the Atlantic (226 compared to 515 peak IAC flights), Figure 10 shows that like the Atlantic the peak is quite broad. Flight hour activity rises relatively quickly at 0100 GMT (roughly 0600 Bombay time) and remains relatively high until about 1200 GMT (1700 Bombay time). Because of the considerable variation in the peaking characteristics of the individual IAC areas and the fact that their peaks vary widely in time over the Greenwich day, the basin peak appears to reflect the contribution of many areas rather than the pattern of a few large areas. With the exception of IAC Area I-3 (which is centered over the Southern Indian Ocean), all of the individual IAC areas experience their peak IACs during the broad basin peak.

- Like the Atlantic, many of the individual IAC area peaks reflect a higher percentage of total flight hours than does the basin peak although, of course, the absolute number of flights in the basin peak far exceeds that of any individual IAC area.

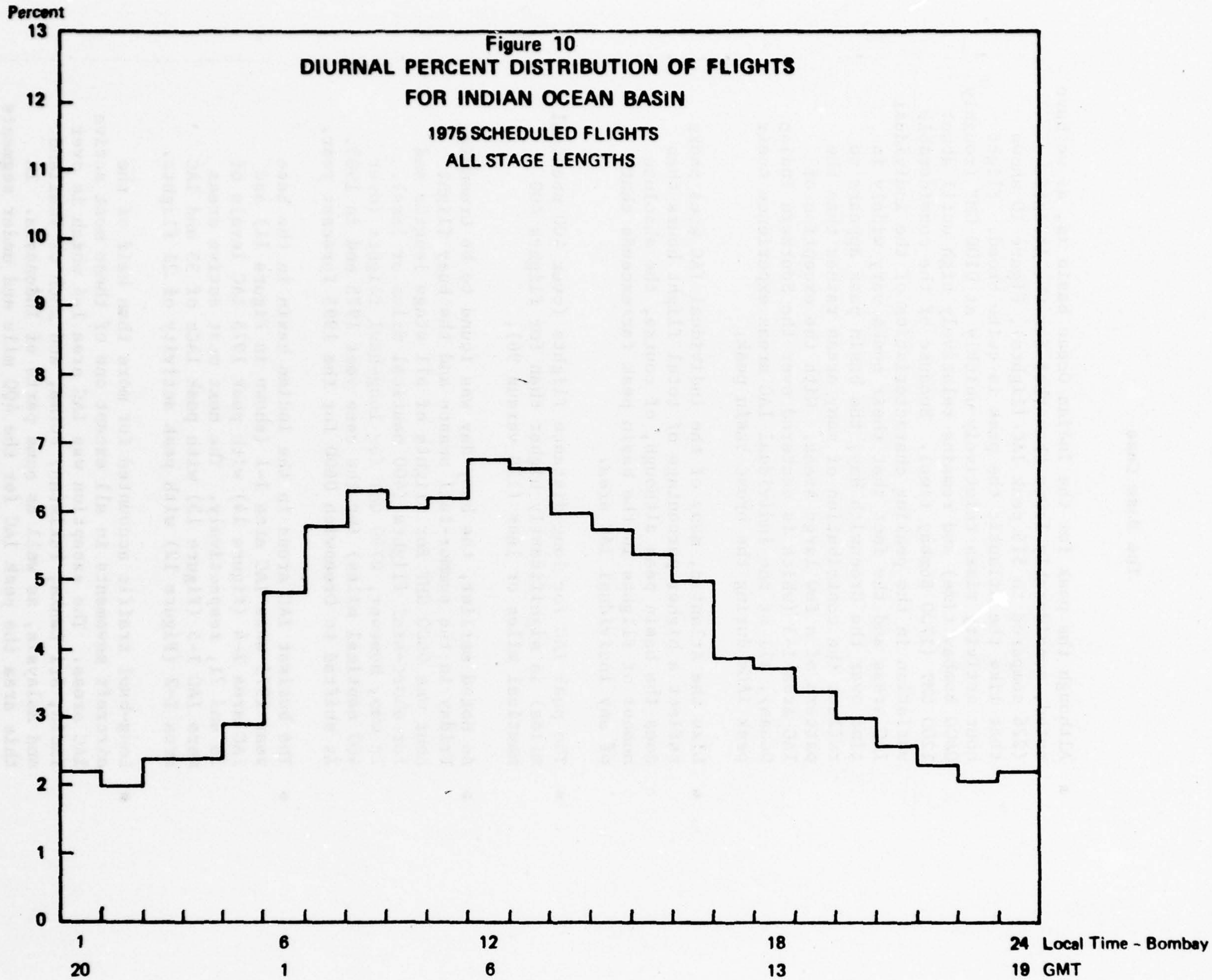
- The peak IAC for long-distance flights (over 400 nautical miles) is significantly higher than for flights 400 nautical miles or less (128 versus 96).

- As noted earlier, the busy day was found to be Greenwich Friday in the summer-fall season and the busy flight hour was 0600 GMT for flights of all stage lengths and for short-haul flights (400 nautical miles or less). It was, however, 0700 GMT for long-haul flights (over 400 nautical miles) for the base year 1975 and in 1985. It shifted to Greenwich 0600 for the 1995 forecast year.

- The busiest IAC areas in the Indian basin in the base year 1975 were IAC area I-1 (shown in Figure 11) and IAC area I-4 (Figure 14) with peak 1975 IAC levels of 58 and 71, respectively. The next most active areas were IAC I-5 (Figure 15) with peak IACs of 35 and IAC area I-2 (Figure 12) with peak activity of 31 flights.

- Long-haul traffic accounted for more than half of the aircraft movements in all except one of these most active IAC areas. The exception was IAC area I-4 which is over India, Sri Lanka, Pakistan, Burma, and much of Thailand and Malaysia, as well as some parts of Indonesia. In this area the peak IAC for the 400 mile and under segments was slightly more, 37 flights, than the peak IAC for long-haul flights, which was 35 movements.

Figure 10
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN OCEAN BASIN
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS



- The diurnal distribution of traffic differs significantly among the various IAC areas. IAC area I-1, Figure 11, which is over the major traffic generating points of Hong Kong, Bangkok, and Singapore, climbs sharply starting at 0800 Hong Kong time (1200 GMT) and reaches its actual peak at 1300 Hong Kong time (0500 GMT). However, the activity is characterized by a relatively broad peak pattern with minor rises running from approximately 0800-0900 local time to about 1900 local time (2400-0100 GMT to 1100 GMT) from which point it gradually steps down to a low point in the very late evening and early morning hours. Local traffic is almost as important as long-haul traffic (27 flights versus 31 flights). In addition to the local traffic, this also is a transit area for traffic moving from Japan through Hong Kong, Bangkok, and/or Singapore to Sydney and other Australian points.

- IAC area I-2, Figure 12, which is primarily over Indonesia with Singapore at its northern border, also is a transit area for both Japan/Singapore/ Australian traffic and for Australian/India/European traffic. Here again the difference between long- and short-haul traffic is quite slight, the long-haul traffic having a peak of 19 aircraft movements at 1000 Greenwich (1700 Jakarta time) while the 400 mile and under traffic has a peak IAC of 17 aircraft movements at 0300 Greenwich (1000 Jakarta time).

  As shown by Figure 12, the general shape of peak activity in this area is quite similar to that in IAC area I-1, rising abruptly at 0700 Jakarta time with multiple peaks between 0900 and 1700 local time and falling off in a gradual stepped activity level from 1900 through 2300 local time.

- Indian IAC area I-3 is centered over the western tip of Australia and the southern Indian Ocean. Its peak activity of 12 movements is primarily influenced by long-haul traffic with 12 flights moving at 1600 GMT or 2400 Perth time. In addition to the intra-Australian activity, which accounts for a broad but relatively low-level peaking from 0900 to 2000, the long-haul traffic is primarily to Singapore and India and going on to Japan or Europe. Figure 13 shows a distinct bimodal pattern but the low level of activity makes it difficult to interpret with assurance.

Figure 11
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN IAC AREA I – HONG KONG/SINGAPORE/THAILAND

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

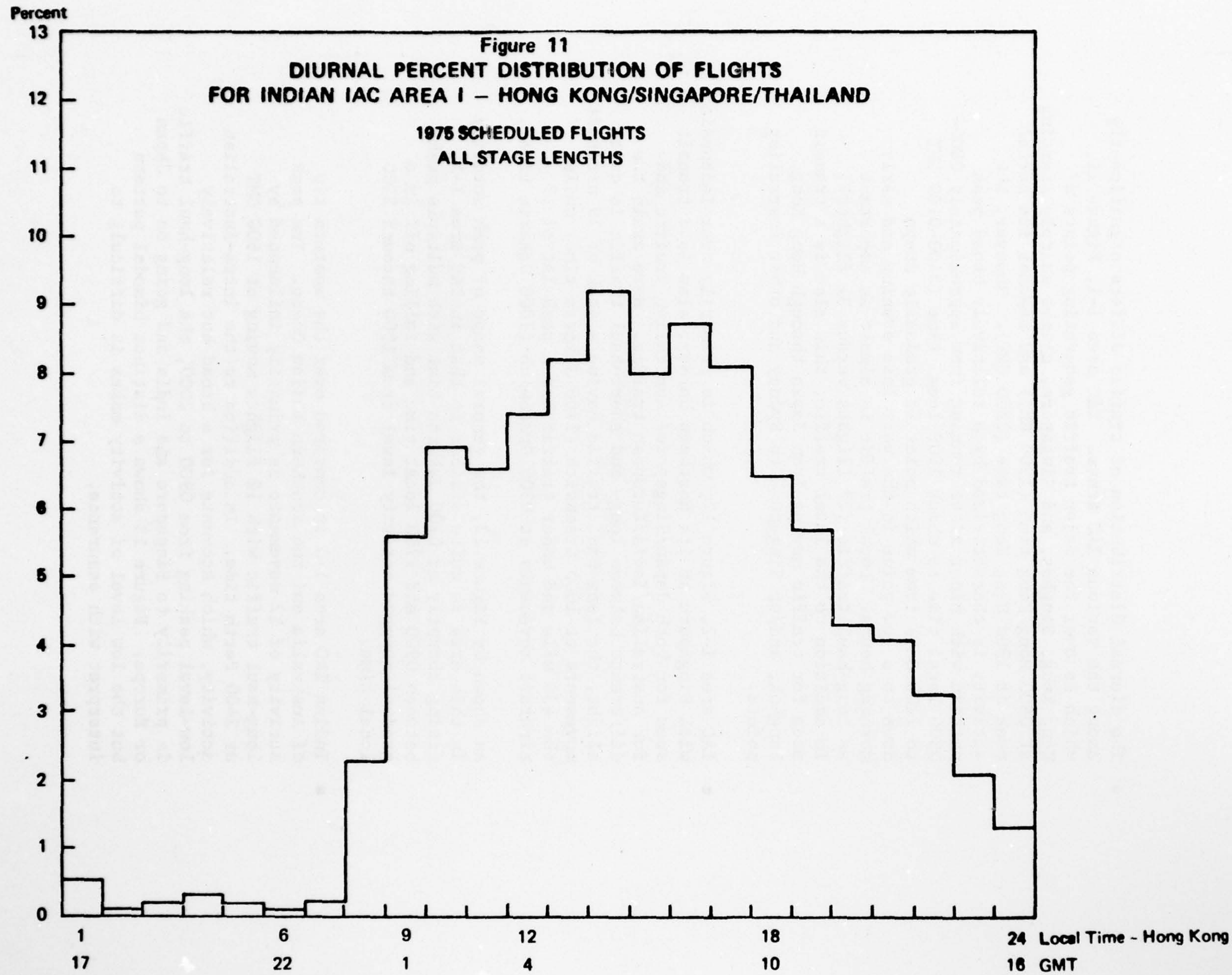


Figure 12

DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR INDIAN IAC AREA 2 – INDONESIA

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

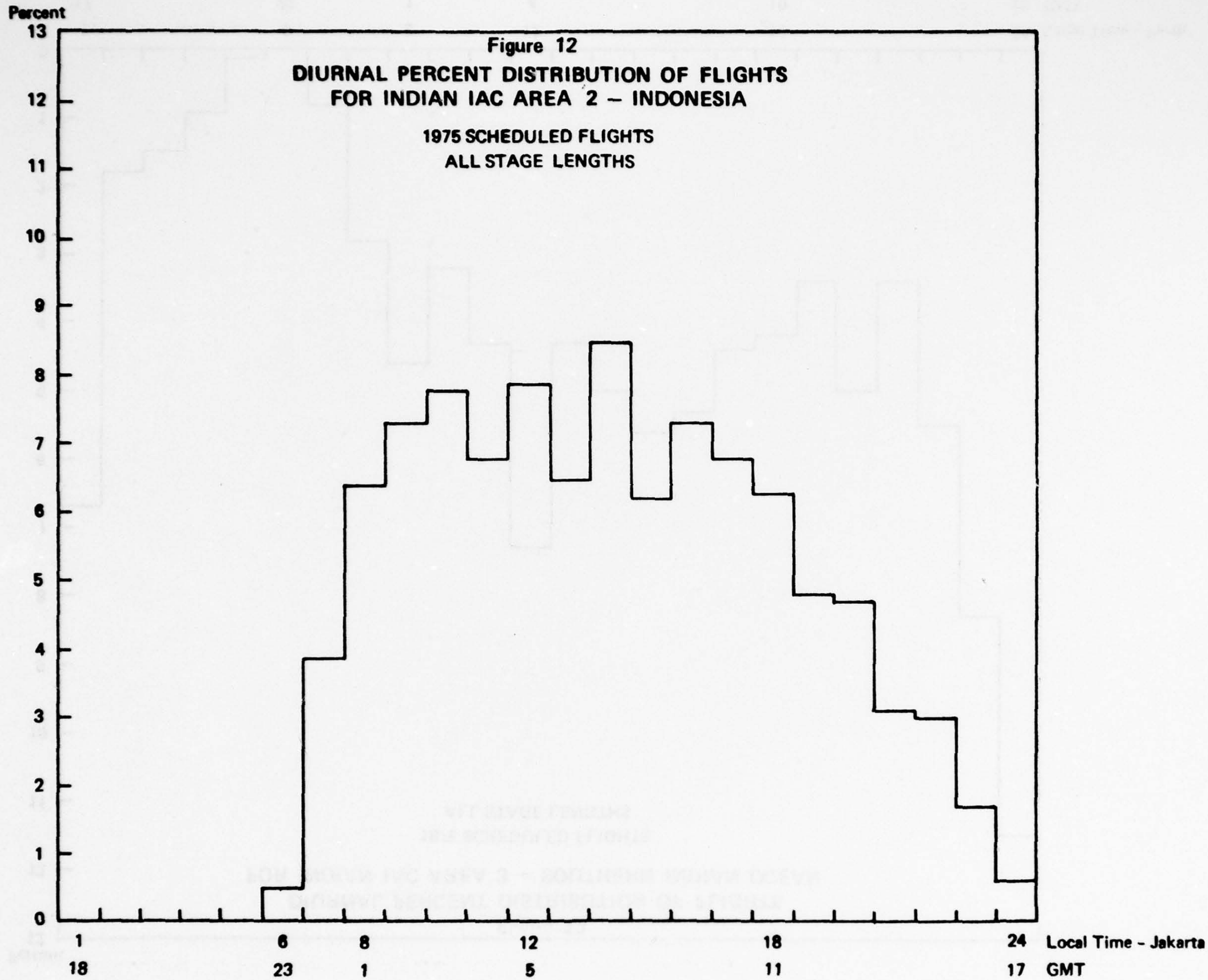
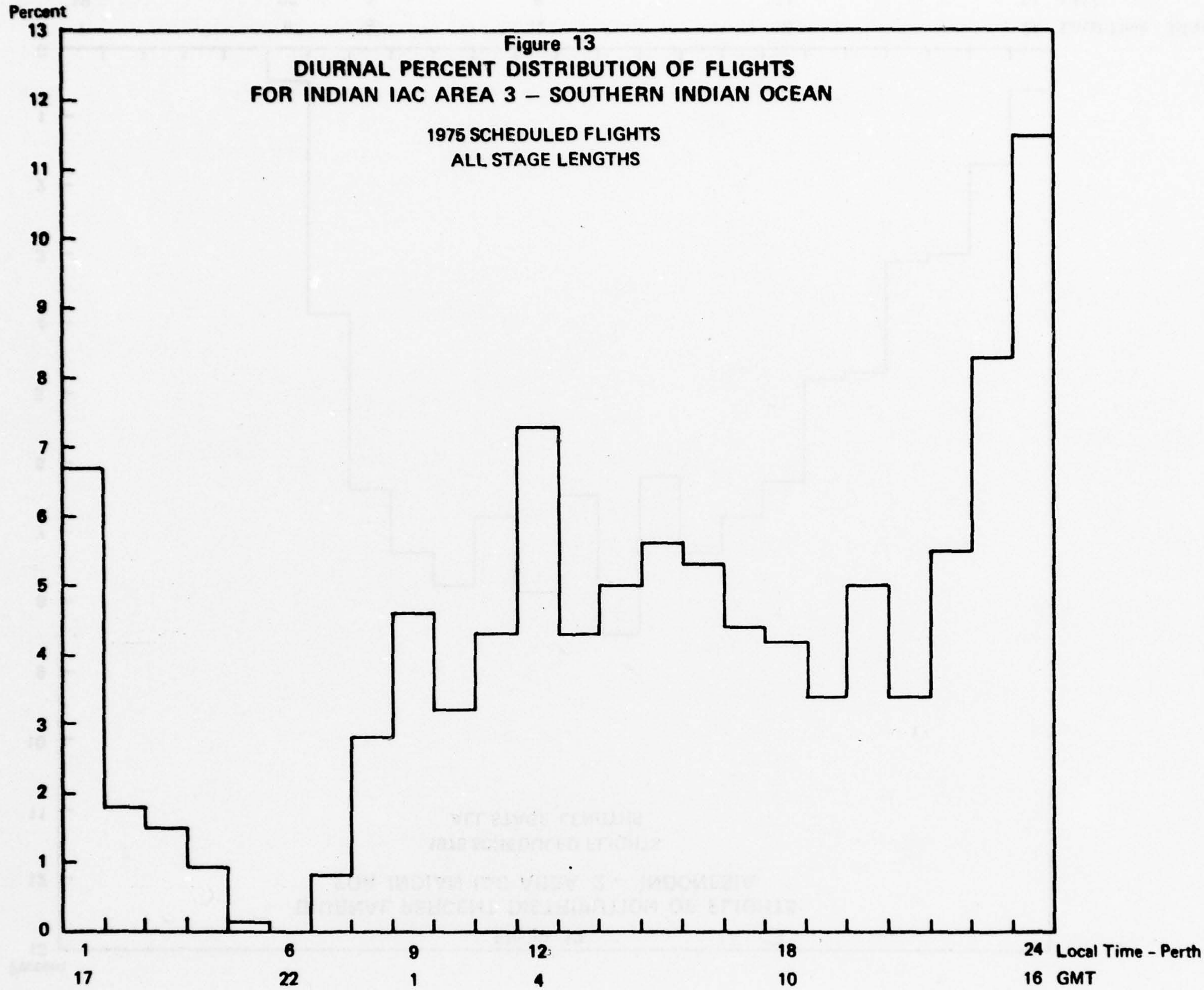


Figure 13
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN IAC AREA 3 – SOUTHERN INDIAN OCEAN

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS



- The most active IAC area, Indian IAC area I-4, with a peak IAC of 71 flights, is shown by Figure 14 to have a somewhat different activity profile than Indian IAC areas I-1 and I-2. Activity does rise abruptly in the early morning hours--0700 Calcutta time--but from a level of activity in the earlier morning hours accounting for between 2 and 3 percent of total flight hours. Further, the distinct peak activity at 0900 Calcutta time (0300 GMT) drops slowly exhibiting an extremely broad level of activity through 1700 local time and continuing a reasonably high level through the end of the day. Significantly, both short-haul--400 miles and less--traffic and long-haul traffic have the same peak activity hour, 0900 local time (0300 GMT).

- The last major activity area, the Middle East (Indian IAC area I-5), as is shown by Figure 15, has almost no clear-cut central tendency at all. The peak activity that does exist extends from 0800 Teheran to 1100 (0500 to 0800 GMT) but there are secondary activity levels extending from 1800 through 2400 and activity in the extremely early morning hours between 0100 and 0400 local time. The long-haul traffic peak activity occurs at approximately 0300 local time (2400 GMT) with 24 flight movements. The short-haul activity, however, peaks at 1000 with 17 flight movements (0700 GMT). The Middle East, of course, is a transit area for traffic moving from Europe to the Far East and Australia/Oceania. Because of its growing wealth, however, it is also an increasingly important generator of both intra-area traffic and locally originating and terminating long-haul traffic to Europe, United States, and the Far East.

- Indian IAC area I-6 which is centered over Afghanistan, northern Pakistan and northern India, including Hindustan, is shown by Figure 16 to have a broad activity level with several peakings. As with the Middle East, it has a peak activity in the early morning hours between 0200 and 0500 Kabul time (2100 to 2400 GMT) as well as a broad daytime activity running from approximately 0800 to 1400 local time but continuing a level of activity from 1600 to 1800. Long-haul traffic peaks about 0300 local time (2200 GMT) with approximately 7 flights and short-haul peaks with about the same level of activity at 1200 local time (0700 GMT).

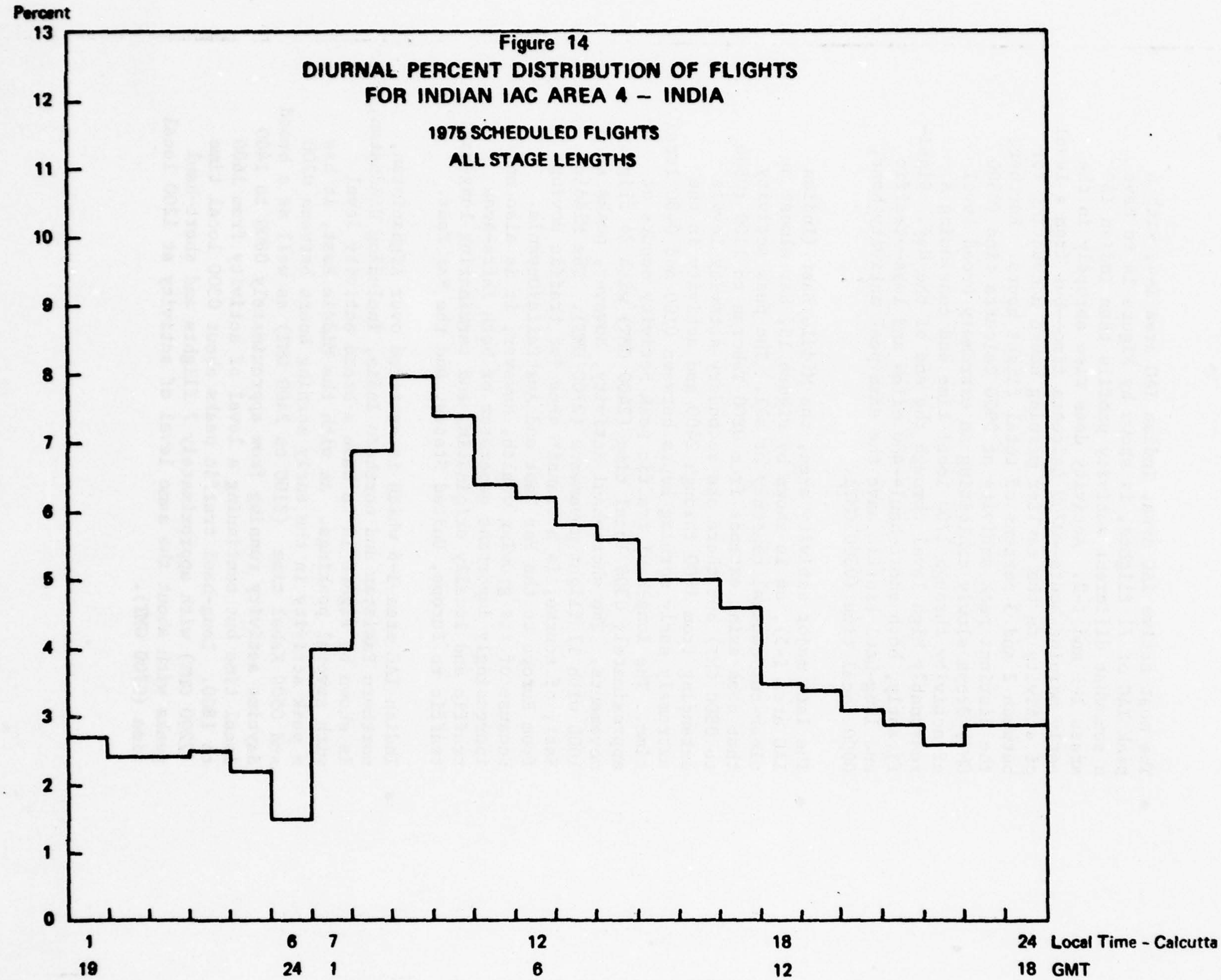
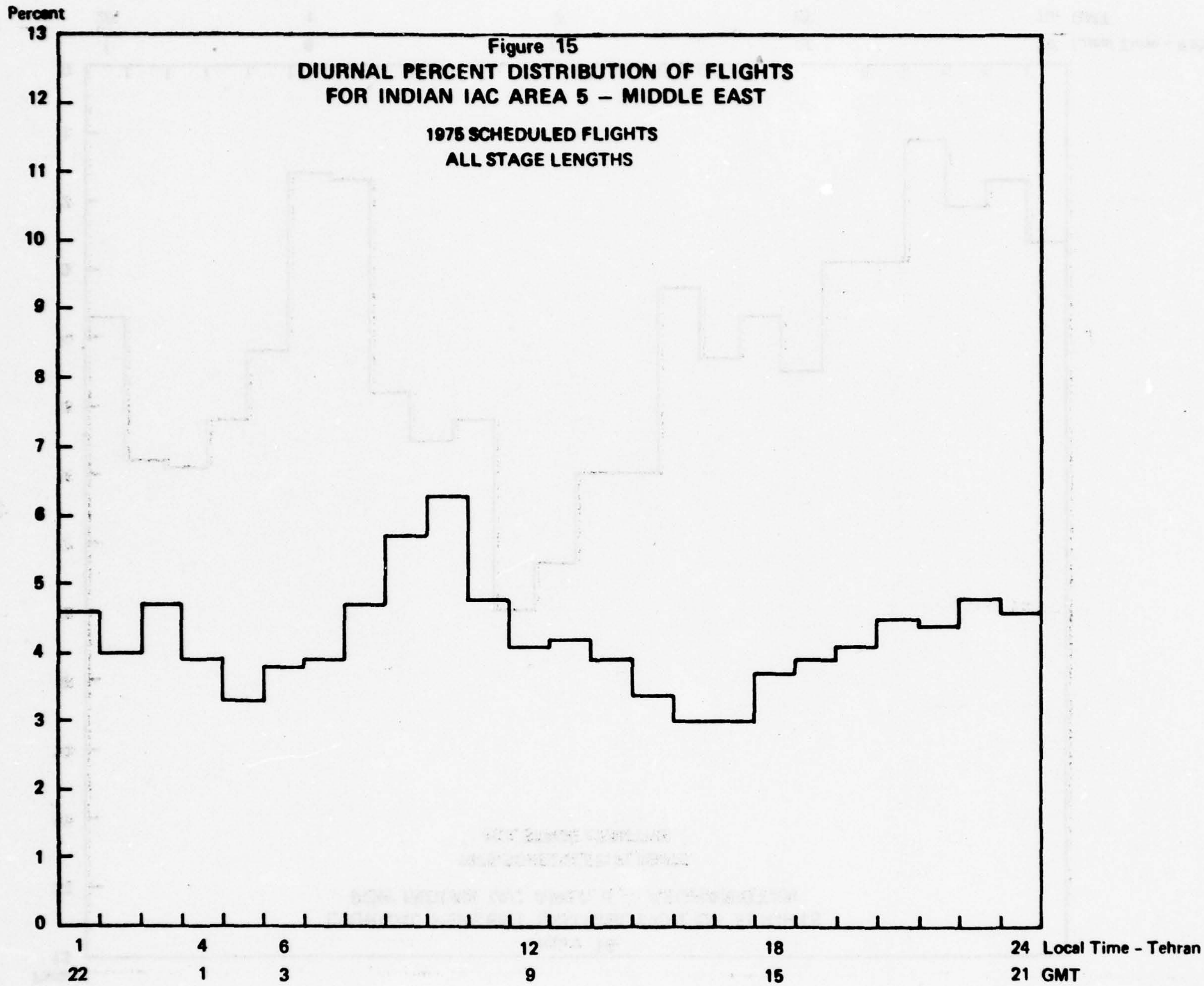


Figure 14
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR INDIAN IAC AREA 4 – INDIA

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

Figure 15
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN IAC AREA 5 – MIDDLE EAST

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS



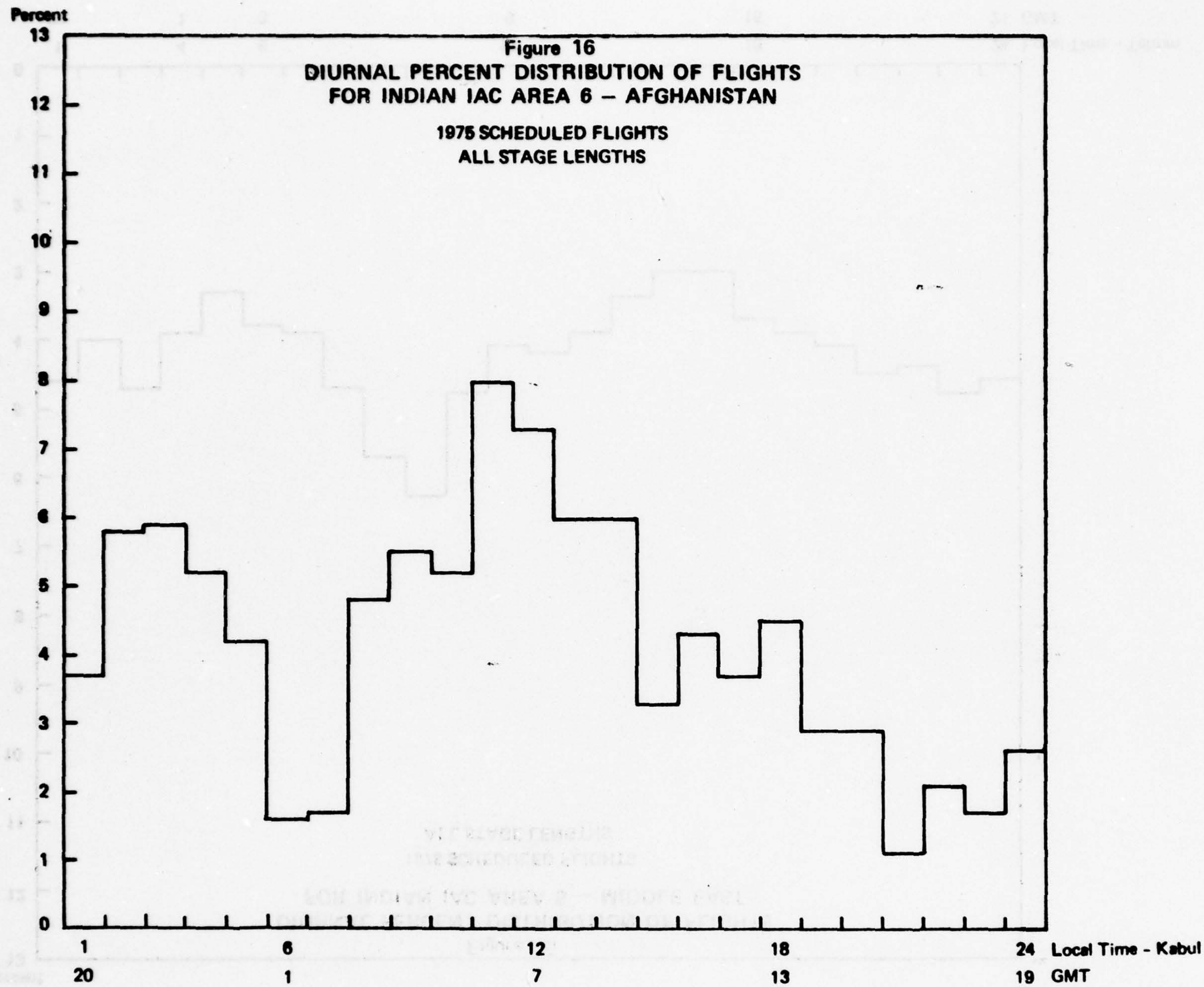


Figure 16
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN IAC AREA 6 – AFGHANISTAN

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

- The remaining Indian area IACs lie over the People's Republic of China, Outer Mongolia, and the USSR. We know that overflights are somewhat restricted in these areas and we have reason to believe that local and even some long-haul activity may not be fully reflected in the OAG tapes. Furthermore, since our model routes traffic by great circle routes, it may show some traffic as traversing these IAC areas that actually flies circuitous routings to avoid overflying them. The activity shown for the base year for these areas therefore must be analyzed with extreme caution, recognizing the high degree of uncertainty with respect to the actual level and character of activity.

- Indian IAC area I-7, Figure 17, which is over the southeastern part of the People's Republic of China, is centered on Canton and also includes Hong Kong. This shows an extremely concentrated level of activity running from 0900 Hong Kong time to 1900 (0100 to 1100 GMT) with 24 percent of the traffic concentrated between 1400 and 1900 local time. The general shape of this peak strongly resembles that of the Hong Kong/Bangkok/Singapore area (IAC I-1) and the Indonesian I-2 area as well as the Pacific area centered on Japan. It is probable that most of the activity reflected in our analysis is moving to and from Hong Kong and may be actually moving circuitously over water to avoid mainland PRC. The activity level in this IAC area is higher than in the Afghanistan and southern Indian Ocean areas (I-6 and I-3) with approximately 16 flights moving at 1400 local time. These are primarily long-haul flights although the peak for short-haul traffic is the same.

- Indian IAC area I-8 is almost entirely over the mainland of the People's Republic of China. As shown in Figure 18, it has a very incoherent pattern with a total peak IAC of only 9 flights peaking at 0200 GMT (1000 Peking time) and with over 35 percent of the movements concentrated between 0900 and 1100 local time. There is a secondary peaking, however, falling between 1600 and 2200 local time with a dropoff at 1900. This is apparently predominantly long-haul traffic whereas the earlier peaking is short-haul traffic.

  However, without any real knowledge of the adequacy of our information we cannot make very valid interpretations with so confused a presentation.

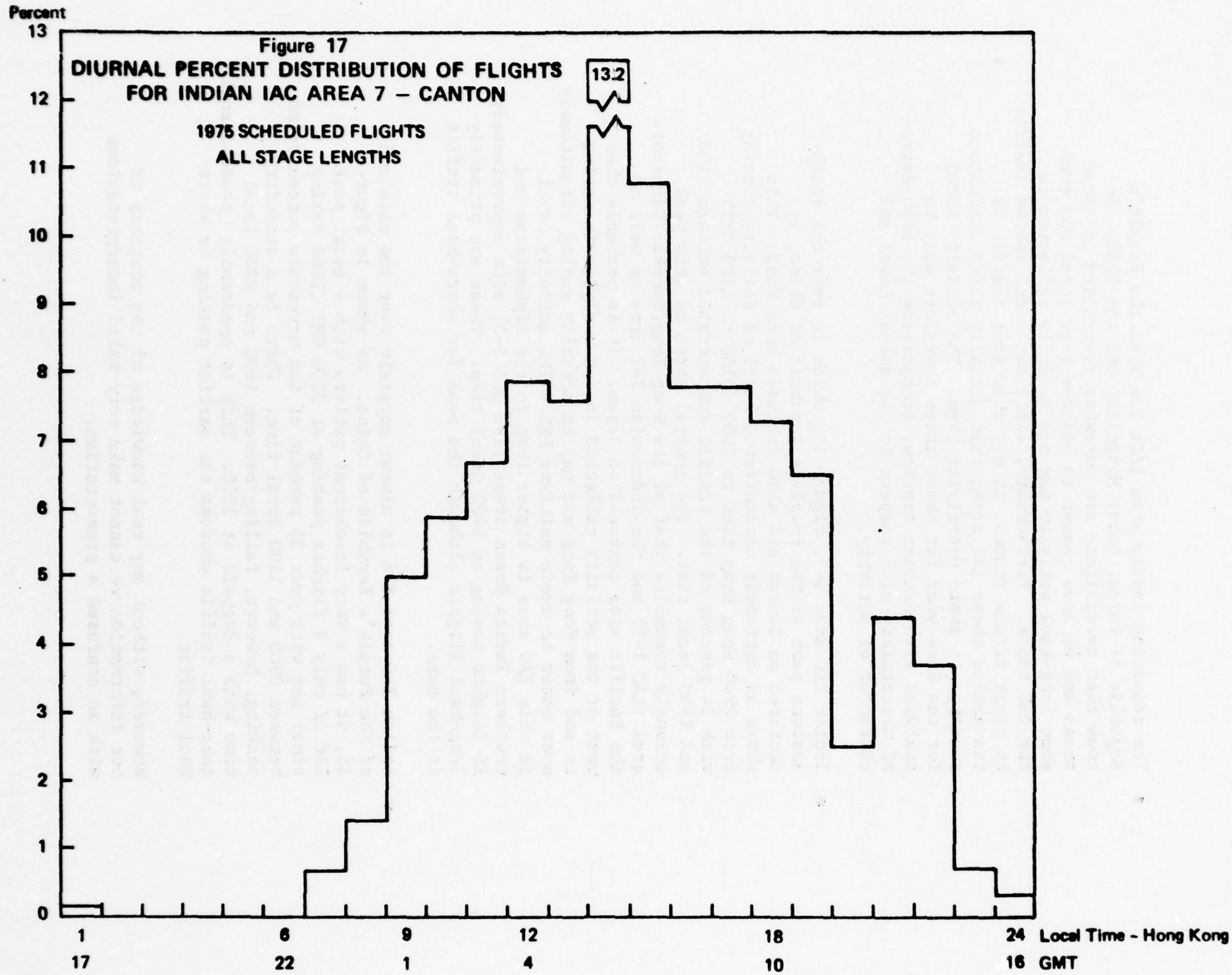


Figure 17
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR INDIAN IAC AREA 7 – CANTON
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

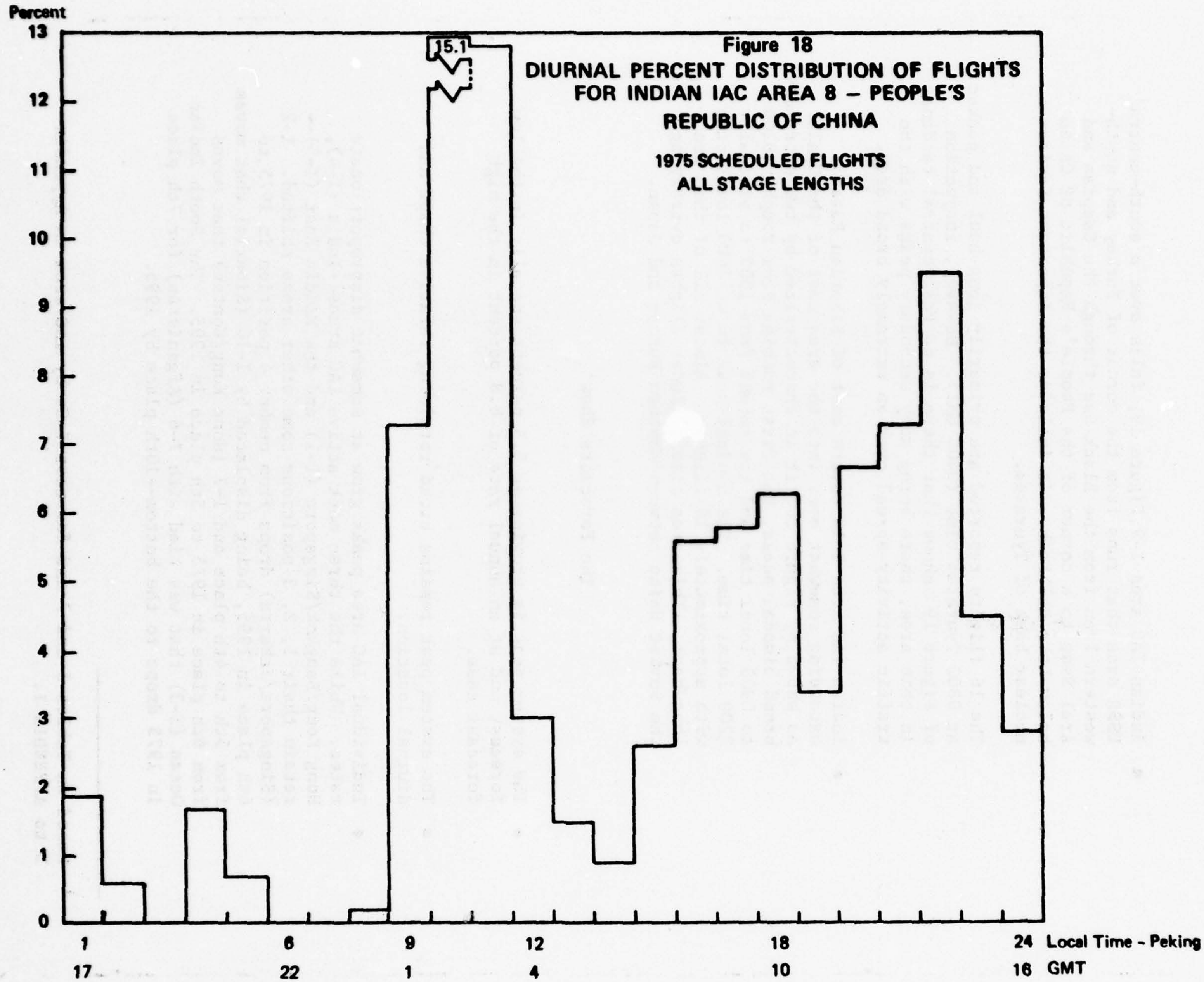


Figure 18
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR INDIAN IAC AREA 8 – PEOPLE'S REPUBLIC OF CHINA
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

- Indian IAC area I-9 Figure 19, falls over a south-central USSR area that runs from the corner of Turkey and north-western Iran from the Black Sea through the Caspian and Aral Seas to a corner of the People's Republic of China below Lake Balkhash. It includes the important Soviet nuclear base of Tyuratam.

  The 16 flights reported are primarily long-haul and peaked at 0800 Tyuratam time (0400 GMT). However, inspection of Figure 19 shows that there is no real central tendency in this area, there being many secondary peaks with the traffic activity spread over an extremely broad area.

- Indian IAC area I-10 covers most of Siberian Russia extending somewhat over into the area east of the Urals. As shown by Figure 20, it is characterized by two extremely broad bimodal peaks, the first running from roughly 0200 to 0900 local time and the second from 1300 to virtually 2200 local time. The nominal peak is at 1400 local time with approximately 19 flights. Almost all of them are long-haul. This area also includes flights overflying the Soviet Union between Western Europe and Japan.

The Forecasts Show[1]

- The system peak is growing at 5.5 percent annually in the low forecast and at an annual rate of 8.8 percent in the high forecast case.

- The system peak remains broad retaining relative shape and diurnal location.

- Individual IAC area peaks grow at somewhat disproportionate rates. While the three most active IAC areas--India (I-4), Hong Kong/Bangkok/Singapore (I-1) and the Middle East (I-5)--retain their 1, 2, 3 positions some other areas shifted. I-2 (Singapore/Jakarta) drops from number 4 position in 1975 to 6th place in 1995, being displaced by I-10 (Siberia) that moves from 5th to 4th place and I-7 (Hong Kong/Canton) that moves from 6th place in 1975 to 5th place in 1995. The South Indian Ocean (I-3) that was tied with I-6 (Afganistan) for 7th place in 1975 drops to the bottom--10th place by 1995.

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1 Based on Tables 1 and 7 and forecast IACs by IAC area in Appendix D to APPENDIX I.

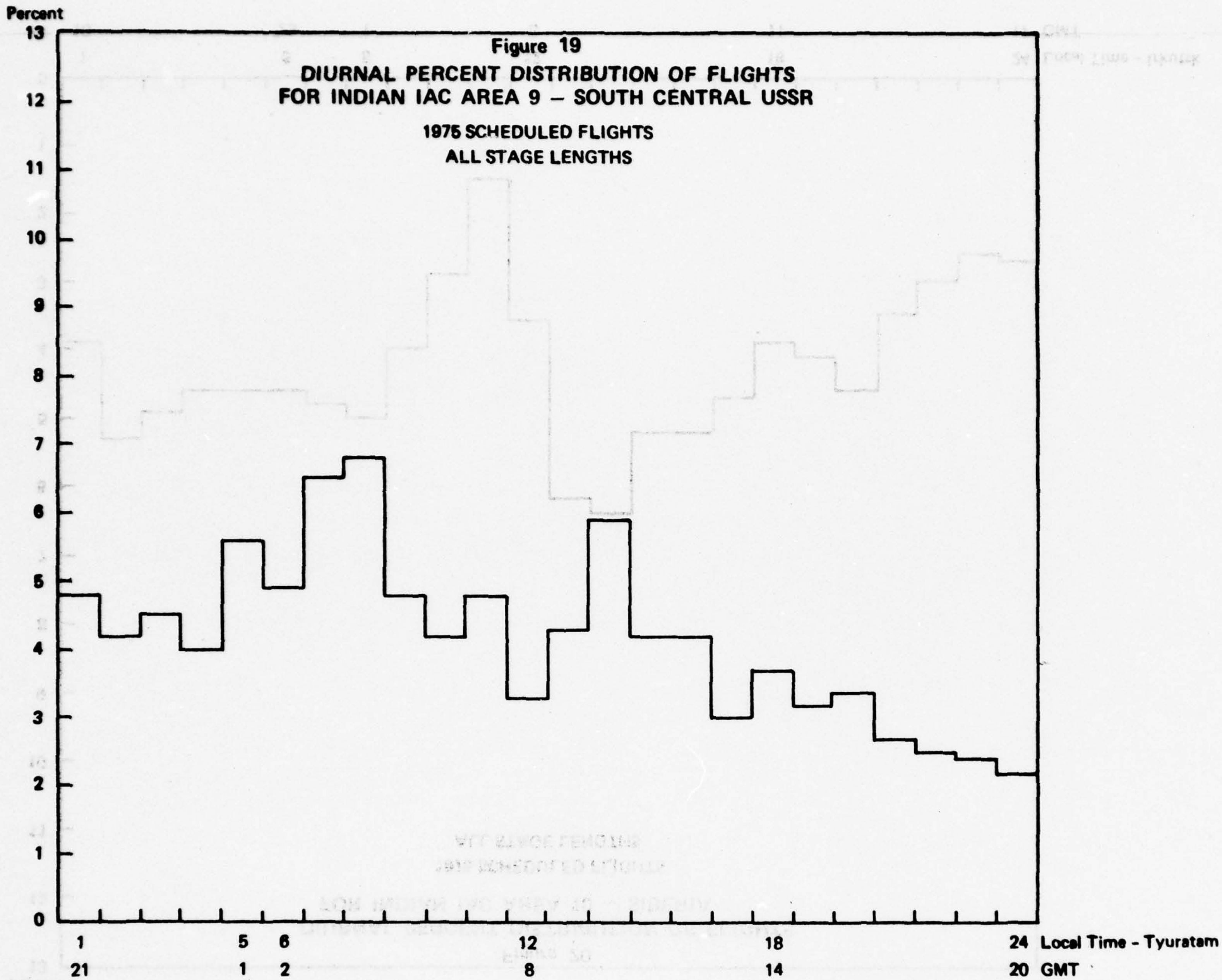
Figure 19
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN IAC AREA 9 – SOUTH CENTRAL USSR
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS
Percent
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
5
6
12
18
24
Local Time - Tyuratam
21
1
2
8
14
20
GMT

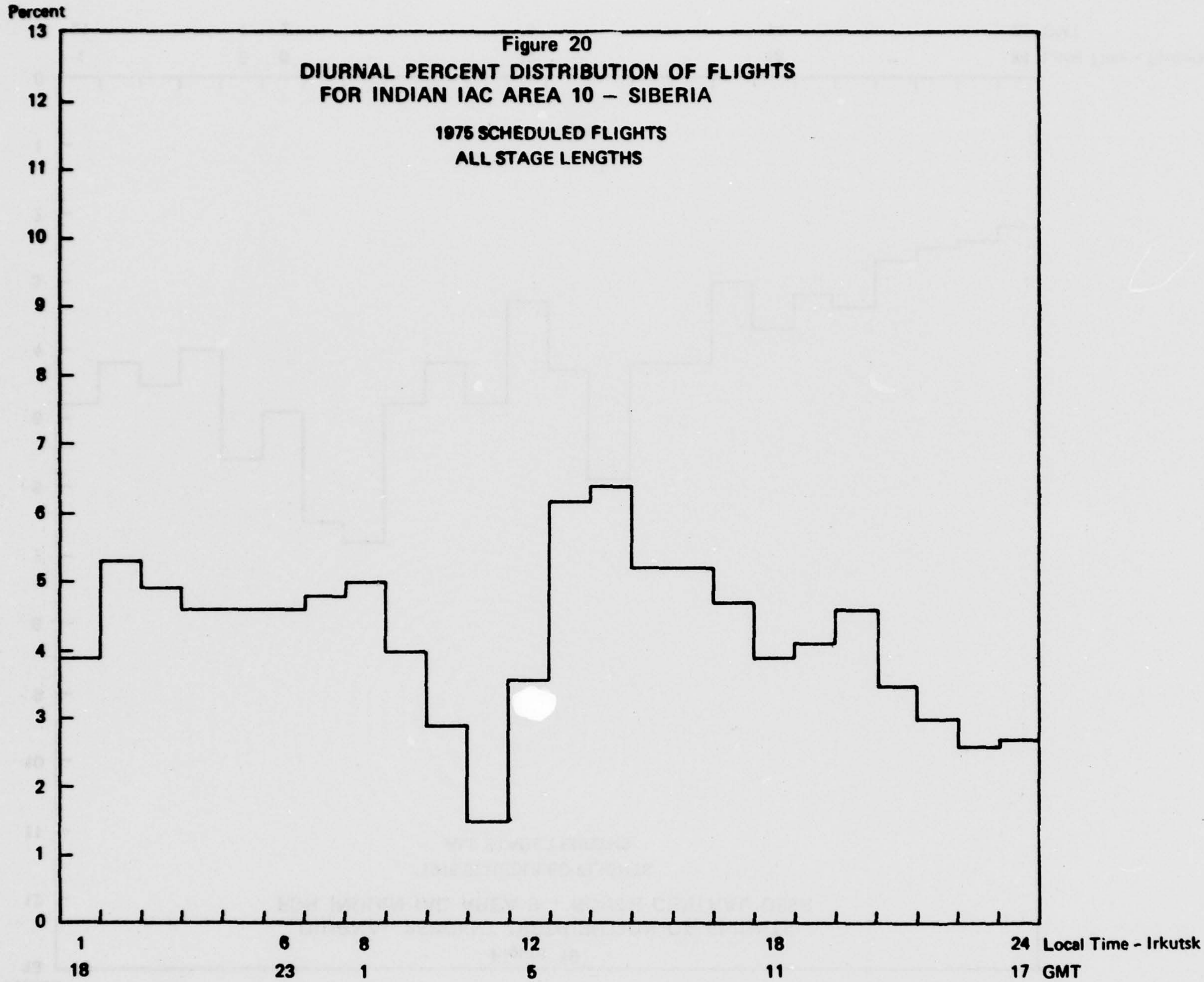

Figure 20
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR INDIAN IAC AREA 10 – SIBERIA

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

- Except for the further strengthening of Siberia as a major traffic flow area, however, there is little significant shift in traffic flows throughout the basin. The relative dominance of the Indian, Hong Kong/Bangkok/Singapore (and Tokyo and Sydney the two anchors of their traffic flow crescent) IAC areas remains unchanged.

- The temporal and spatial peaking characteristics remain similar for the projected traffic to those identified in the baseline (1975) analysis. The busy day of the summer-faLl season remains Greenwich Friday and 0600 GMT remains the busy flight hour for all flights and for flights 400 n.m. or less.

- For flights over 400 n.m., however, the busy flight hour was 0700 hours GMT for 1975 and 1985 but moves to 0600 GMT in 1995.

- The major factor of the forecasts is the much higher growth rate exhibited by the Indian basin for all scenarios, types of traffic and stage lengths than the Atlantic and Pacific basins.

Since by far the heaviest known movement in the area is the crescent movement from Japan through and within IAC area I-1 (Hong Kong/Bangkok/ Singapore) to Australia, the characteristics of this movement are of paramount concern. With the advent of the B-747 SP, which would permit nonstop Japan/ Sydney movements with significant loads, the possibility exists of a shift of some significant part of this traffic from its present crescent routing to nonstop movements between any of the several pairs of points in the area of concern.

In Figure 21 we have superimposed the peaking patterns of Pacific area P-1 (which includes the Japan/Korea area and the traffic moving from this area to Hong Kong and points south), Pacific area P-9 (which includes most of Australia as far east as Sydney), and Indian areas I-1 and I-2 (which are the Hong Kong/Bangkok/Singapore area and the Singapore/Jakarta area). This composite histogram shows that the bulk of the traffic peaks between Greenwich 2400 and Greenwich 1100 (0500 and 1600 Bombay time) which roughly coincides with the

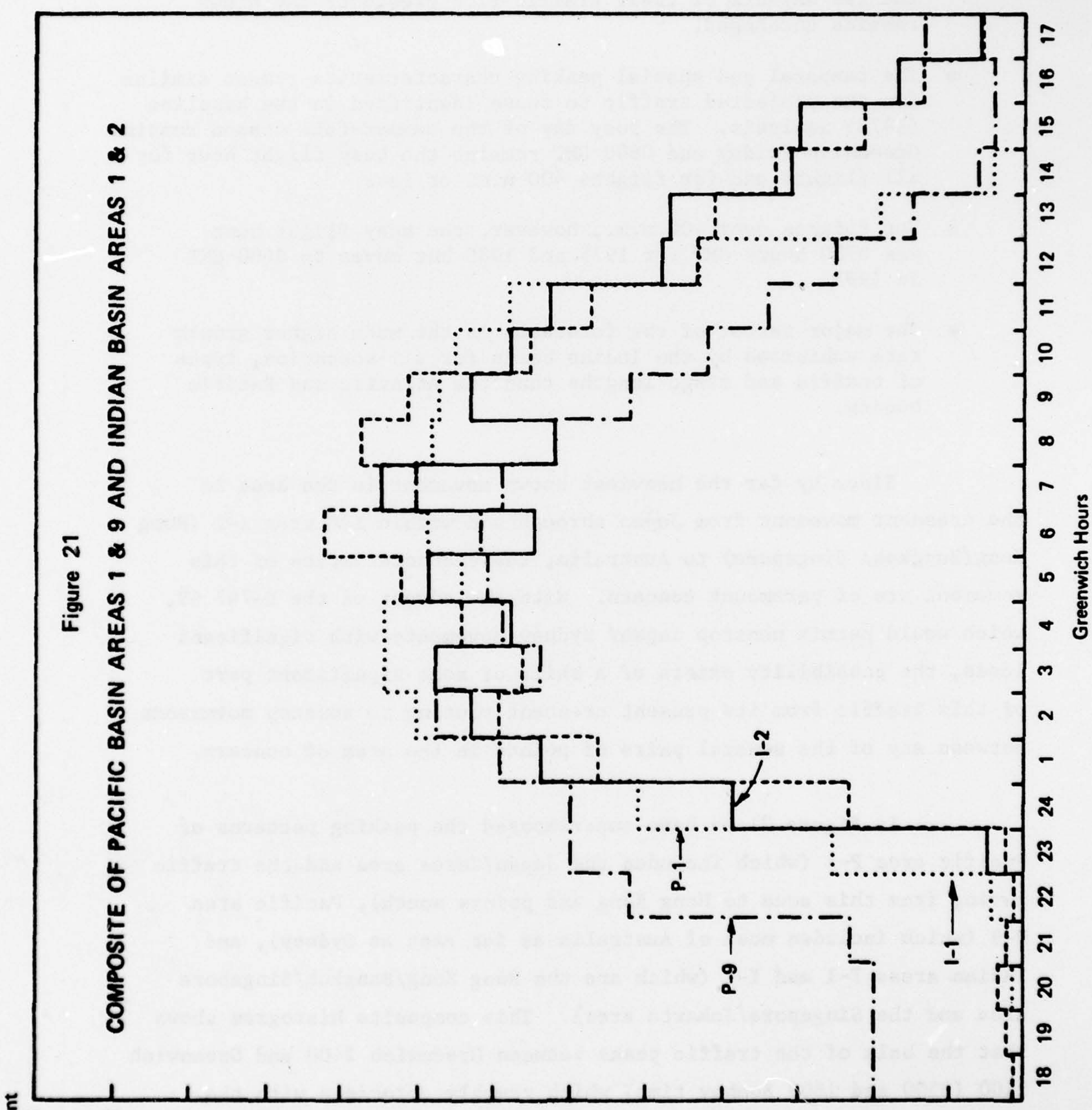

Figure 21

COMPOSITE OF PACIFIC BASIN AREAS 1 & 9 AND INDIAN BASIN AREAS 1 & 2

peak for the Indian Ocean basin as a whole. This peak is so broad as to allow significant variation in scheduled activity within it without significantly altering its shape. It appears therefore that traffic patterns within this western Pacific, eastern Indian Ocean corridor will not be materially altered so far as peaking characteristics are concerned either by increased use of long-haul subsonic aircraft or probably by supersonic aircraft should they be introduced into service in this area.

3. The Composition of Indian Ocean Basin Activity

Because the regions that compose the Indian Ocean basin traffic are so broadly defined, the base period 1975 contribution of the major scheduled routes to the traffic in the individual IAC areas was studied independently. Table 11 compares 1975 peak IACs for major routes and all air routes in the Indian Ocean basin, based on all traffic flows.

In most of the Indian IAC areas with heavy all route traffic (i.e. Indian IAC areas I-1, I-4, and I-5) the major routes responsible for much of the total IACs in these areas and for the most part this subset of activity, tends to peak during similar time periods. This pattern suggests that the few major route flows are associated strongly with the area peaking that is observed.

Except for the IAC areas over the USSR and the People's Republic of China, about which not too much information is available, the area is characterized by two major route flows. The largest flow is between Japan, Hong Kong, Bangkok, Singapore, sometimes Jakarta, ending up in Sydney, Australia. The second major traffic movement is from Australia to Singapore and/or Bangkok, India, Pakistan, the Middle East to Europe. This also includes significant traffic between Singapore and Bangkok on the one hand and India, Pakistan, and the Middle East on the other. In addition, traffic moves between India and Pakistan on the one hand and Japan on the other.

Table 11

COMPARISON OF 1975 PEAK IACs FOR MAJOR ROUTES AND
ALL AIR ROUTES IN THE INDIAN OCEAN BASIN (ALL TRAFFIC)

	PEAK IAC AND HOUR (GMT)		MAJOR ROUTES*		
IAC AREA/STAGE LENGTH	MAJOR ROUTES ONLY	ALL ROUTES	1	2	3
Basin (All Areas)					
• All stage lengths	73 (6)	234 (6)			
• Over 400 N.M.	47 (6)	133 (7)			
I-1					
• All stage lengths	23 (6)	60 (6)	Thailand/HongKong	Intra Thailand	Singapore/Thailand
• Over 400 N.M.	22 (6)	32 (6)	Thailand/Hong Kong	Singapore/Thailand	Singapore/Hong Kong
I-2					
• All stage lengths	7 (11)	32 (7)	Singapore/Australia	India/Singapore	-
• Over 400 N.M.	7 (11)	20 (10)	Singapore/Australia	India/Singapore	-
I-3					
• All stage lengths	8 (16)	12 (16)	Intra Australia	Australia/Singapore	Australia/India
• Over 400 N.M.	8 (16)	12 (16)	Intra Australia	Australia/Singapore	Australia/India
I-4					
• All stage lengths	40 (3)	73 (3)	Intra India	India/Thailand	Intra Pakistan
• Over 400 N.M.	23 (3)	36 (3)	Intra India	Intra Pakistan	-
I-5					
• All stage lengths	7 (7)	37 (7)	Intra Saudi Arabia	-	-
• Over 400 N.M.	3 (19)	26 (24)	Intra Saudi Arabia	-	-
I-6					
• All stage lengths	8 (6)	12 (6)	Intra Pakistan	Intra India	-
• Over 400 N.M.	3 (5)	8 (22)	Intra Pakistan	Intra India	-
I-7					
• All stage lengths	6 (6)	16 (6)	Japan/Hong Kong	India/Hong Kong	Australia/Hong Kong
• Over 400 N.M.	6 (6)	14 (6)	Japan/Hong Kong	India/Hong Kong	Australia/Hong Kong
I-8					
• All stage lengths	1 (13)	9 (2)	India/Japan	-	-
• Over 400 N.M.	1 (13)	6 (14)	India/Japan	-	-
I-9					
• All stage lengths	1 (22)	17 (4)	-	-	-
• Over 400 N.M.	1 (22)	14 (4)	-	-	-
I-10					
• All stage lengths	3 (23)	20 (7)	-	-	-
• Over 400 N.M.	3 (23)	19 (7)	-	-	-

* Ranked by number of daily entries in descending order
\- No major routes identified

4. <u>The Prospect of Increased Trade and Air Commerce With the People's Republic of China and Its Impact on Projected IACs</u>

Since 1949, the People's Republic of China (RPC) practiced an economic and political policy which virtually isolated the PRC from the rest of the world. The PRC emphasized the development of a totally self-sufficient economy. Throughout the 1950s and 1960s, the PRC emphasized political indoctrination and advocated a labor-intensive economy based on the concept of "mass mobilization" whereby thousands of people would build bridges and dams using archaic methods. The PRC felt this approach was well suited to its quest for a communist society. It criticized economic policies oriented towards capital-intensive production and international trade, particularly those of the USSR, as too "capitalistic". It felt these policies led to a class society and would increase the PRC's dependence on other countries. It condemned the USSR as abandoning communism.

Since 1970, the PRC has gradually opened its doors to the rest of the world. Under new leadership, a policy of more relaxed relations with the outside world has been adopted. Full diplomatic relations have been established with some western countries and political ties with others are now being established, as demonstrated by the exchange of diplomats between the PRC and the U.S. in the early 1970's. Recent events and press releases indicate that the PRC is placing a greater emphasis on economic development, improving the likelihood of increased trade and air commerce between the PRC and the rest of the world.

The likelihood of increased trade is supported by the recent expansion of international aviation services by the Civil Aviation Administration of China (CAAC) which controls all aviation in the PRC. Since 1970, routes have been inaugurated to Iran, Hungary,

Albania, Russia, Japan, Pakistan, Turkey, Greece, Italy, Switzerland, and France. It is reported[1] that other routes to cities in North America, Africa and Asia are also planned.

An examination of existing PRC international air traffic shows that the cities of Peking and Shanghai serve as the country's primary origin-destination points. Since our forecast analysis is limited to a twenty-year period (1975-95), we can assume that these cities will continue to serve as the major points in the PRC throughout the forecast period.

Based on this assumption, the effects of increased air travel to and from the cities of Peking and Shanghai can be evaluated in terms of:

- the impact on the forecasted peak IAC for relevant IAC areas
- the impact on the present diurnal distribution of IAC's for relevant IAC areas
- the overall impact on transoceanic communication requirements

Shanghai is situated in IAC area P-1 which is one of the busiest IAC areas in the Pacific Ocean basin. Traffic within the area is dominated by the triangular flow between Japan (Osaka and Tokyo), Korea (Seoul) and Taiwan (Taipei). Activity in this area is closely related to the crescent flow of traffic from Tokyo to Sydney via Hong Kong/Bangkok/Singapore.

We anticipate that traffic east of Shanghai will stop and frequently stop-over at Tokyo and traffic west will stop or stop-over at Hong Kong. This is because these cities should continue to be major Asian trade and tourist centers during the next twenty years. Increased air traffic to and from Shanghai should then increase the peak IAC in areas P-1 (Shanghai and Tokyo), I-1 (Hong Kong) and I-7

1 Flight International, 9 April 1977

(Canton/Hong Kong). These additional aircraft movements should increase transoceanic communication requirements.

The increase in traffic to Shanghai should consist of new aircraft movements as well as a shifting of movements from Tokyo/Taiwan to Tokyo/Shanghai and from Hong Kong/Taiwan to Hong Kong/Shanghai. This is because we view the PRC and Taiwan as competing countries. The shift or substitution of traffic from Taiwan to Shanghai should offset the magnitude of the increases in peak IAC's in areas P-1, I-1 and I-7 caused by Shanghai traffic.

Even though Shanghai traffic is expected to increase activity in areas P-1, I-1 and I-7, it should not shift or significantly affect the diurnal distribution of flights in these areas. This is because Shanghai traffic is expected to be influenced by present Hong Kong and Tokyo flight schedules and should conform to the present diurnal distribution of flights depicted on both areas (see Figures 11, 17 and 26 for the diurnal distribution of flights for areas I-1, I-7 and P-1, respectively.) Furthermore, Shanghai traffic should represent only a small portion of traffic in both areas.

Peking is situated in IAC area I-8, which encompasses most of the PRC. For reasons discussed above, we anticipate that travel east of Peking will stop at Tokyo and traffic west will stop at Hong Kong. An increase in Peking traffic should then increase peak IAC's in areas I-8 (Peking), P-1 (Japan), I-1 (Hong Kong) and I-7 (Canton/Hong Kong). These added aircraft movements should increase transoceanic communication requirements.

Similar to Shanghai traffic, the increase in traffic to Peking should consist of new activity as well as a shifting of activity from Hong Kong (Taiwan to Hong Kong/Peking) and from Japan/Taiwan to Japan/Peking. The shift or substitution of traffic from Taiwan to Peking should offset the magnitude of the increase in peak

IAC's in areas P-1, I-1 and I-7 caused by Peking traffic.

The increase in aircraft movements in areas P-1 (Japan), I-1 (Hong Kong) and I-7 (Canton/Hong Kong) due to Peking traffic should not shift or significantly affect the diurnal distribution of traffic in these areas. This is because Peking traffic should represent only a small portion of the total traffic in both areas. Furthermore, since Peking traffic is expected to be related to Hong Kong and Tokyo traffic and flight schedules, the increased traffic should conform to the present broad peaking of flights in both areas.

Very little information is available concerning the diurnal distribution of flights in IAC area I-8. Since we anticipate that future international Peking traffic will probably be linked to Hong Kong and Japan traffic, the diurnal distribution of future international flights in area I-8 (Peking) should be influenced by the distribution in areas I-1 (Hong Kong), I-7 (Canton/Hong Kong), and P-1 (Japan). As Peking traffic increased over the years, the distribution in area I-8 should resemble the broad peaking of flights in areas P-1, I-1 and I-7.

D. Findings: Pacific Ocean Basin

The analysis of the Pacific Ocean basin activity proceeded in the same fashion reported for the Indian Ocean basin. The September 1975 version of the OAG was used to calculate IACs for the Pacific Ocean basin and its constituent IAC areas. Since the activity in the basins is influenced by the same (broadly defined) interregional flows,[1] the busy day of Friday was defined for the Pacific Ocean basin as well as the Indian Ocean basin.

This section is divided into three parts:

- Base and forecasted (high/low) Pacific Ocean basin IACs by stage length
- IACs by IAC areas and time of day
- Composition of Pacific Ocean basin activity

1. Base and Forecasted (High/Low) Pacific Ocean Basin IACs by Stage Length

Table 12 presents both a high and low forecast based on optimistic and pessimistic assumptions for years 1985 and 1995. The forecasts are further broken down between forecasts of "scheduled only" traffic and "all traffic" and by flight stage lengths presenting forecasts for "all stage lengths", for "400 nautical miles or less", and for "longer than 400 nautical miles". The busy hour of the busy day (Greenwich Friday) was found to be 0300 Greenwich time for flights of all stage lengths and for flights longer than 400 nautical

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1 The region pairs that define the eligible flights include flows from all world regions to and from the Middle East, the Far East, and Australasia/Oceania. In addition, Hawaii and Alaska were permitted to be eligible orgins or destinations for flights with their other ends in the United States, Canada or Europe.

Table 12

FORECAST PACIFIC BASIN PEAK IACs FOR 1975, 1985, AND 1995

Case	1975		1985	1995
	BASED ON 11 IAC AREAS			
	FLIGHTS OF ALL STAGE LENGTHS			
All Traffic	396(3)	(HI)	785(3)	1727(3)
		(LO)	589(3)	881(3)
Scheduled Only	360(3)	(HI)	713(3)	1573(3)
		(LO)	531(3)	793(3)
	FLIGHTS OF 400 NAUTICAL MILES OR LESS			
All Traffic	213(1)	(HI)	410(1)	880(1)
		(LO)	309(1)	453(1)
Scheduled Only	198(1)	(HI)	379(1)	822(1)
		(LO)	284(1)	417(1)
	FLIGHTS OF LONGER THAN 400 NAUTICAL MILES			
All Traffic	191(3)	(HI)	388(3)	870(3)
		(LO)	291(3)	442(3)
Scheduled Only	167(3)	(HI)	339(3)	759(3)
		(LO)	252(3)	381(3)

NOTE: These data were derived using the late summer and fall season Reuben H. Donnelley Official Airline Guide (OAG) data base for 1975 and interregional traffic forecasts from SRI. The busy day in all cases was Greenwich Friday. The busy flight hour in Greenwich time is given in parentheses after each IAC estimate.

miles. However, 0100 Greenwich was found to be the busy hour for flights of 400 nautical miles or less. These busy hours remained the same for each stage length for both the forecast years 1985 and 1995.

Traffic for the basin as a whole--"all traffic" and all stage lengths--is projected to grow from 396 flights in 1975 to 1,727 in 1995 for an annual growth rate of approximately 7.7 percent in the high forecast case and from 396 flights to 881 in the low case, representing an annual growth rate of about 4.1 percent.

For "scheduled only" and all age length traffic, Table 12 shows that the peak instantaneous airborne count of flights for the busy hour of the busy day is projected to increase from 360 in 1975 to 1,573 in 1995 under the optimistic (high) forecast,for an annual growth rate of approximatel 7.7 percent. In the low (pessimistic) case, traffic is projected to grow from 360 to 793 flights in the busy hour, for an annual growth rate of 4 percent.

"Scheduled only" flights of 400 nautical miles or less are projected to grow in the optimistic case from 198 flights in 1975 to 822 peak instantaneous airborne flights in 1995, for an annual growth of 7.4 percent. In the pessmistic case, they are projected to grow from 198 flights in the busy hour to 417 flights in 1995, for an annual rate of 3.8 percent.

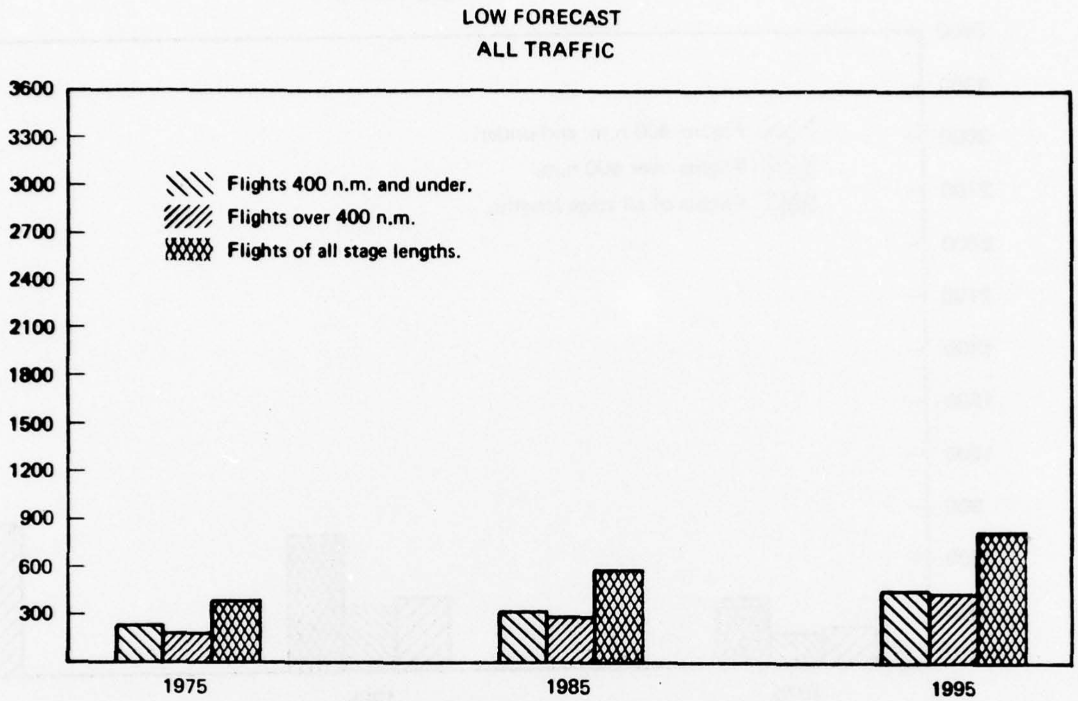
"Scheduled only" flights over 400 n.m. are expected to grow faster than short-haul flights from 167 peak hour 1975 flights to 381, for a 4.2 percent annual growth in the pessimistic case and to 759 for an annual growth of 7.9 percent in the optimistic case.

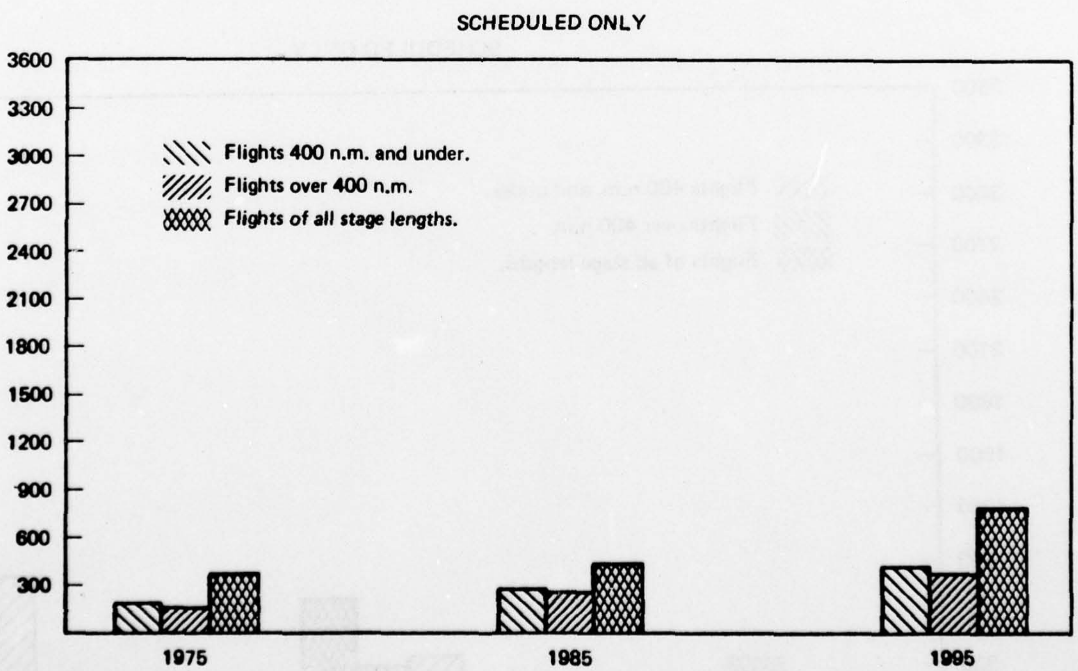
Table 1 above, which compares the percentage growth rates 1975-95 for the three ocean basins, shows that the Pacific basin traffic is projected to grow faster than the Atlantic basin traffic under most circumstances though not as fast as the Indian basin traffic.

Under the high or optimistic growth assumption, Pacific traffic is estimated to grow faster than Atlantic traffic for all stage lengths and for "all traffic" as well as "scheduled" traffic. Under the low forecast, growth in "scheduled" Pacific traffic exceeds Atlantic for all stage lengths, but for "all traffic", Pacific growth exceeds Atlantic in long-haul yet not short-haul or total traffic.

As was true in the Indian Ocean basin, flights of longer than 400 nautical miles are projected to grow somewhat faster than short-haul with "scheduled" flights expected to grow from 167 in the busy hour in 1975 to 759 in the high case in 1995, for an annual growth of 7.9 percent. In the low case they are expected to grow from 167 in 1975 to 381 in 1995, for an annual growth rate of 4.2 percent. As in the case of the Indian basin, the high and the low forecast imply a difference in the IAC level of about a factor of two over the 20-year period. Unlike the case in the Indian basin, there are more short flights (less than 400 nautical miles) contributing to the activity in the base year 1975 than long flights. There is also a greater share of "nonscheduled" activity estimated for the Pacific basin than the Indian basin (roughly 9 percent versus 3 percent respectively) although the numbers in this respect are very crude because of their reliance on models rather than hard data.

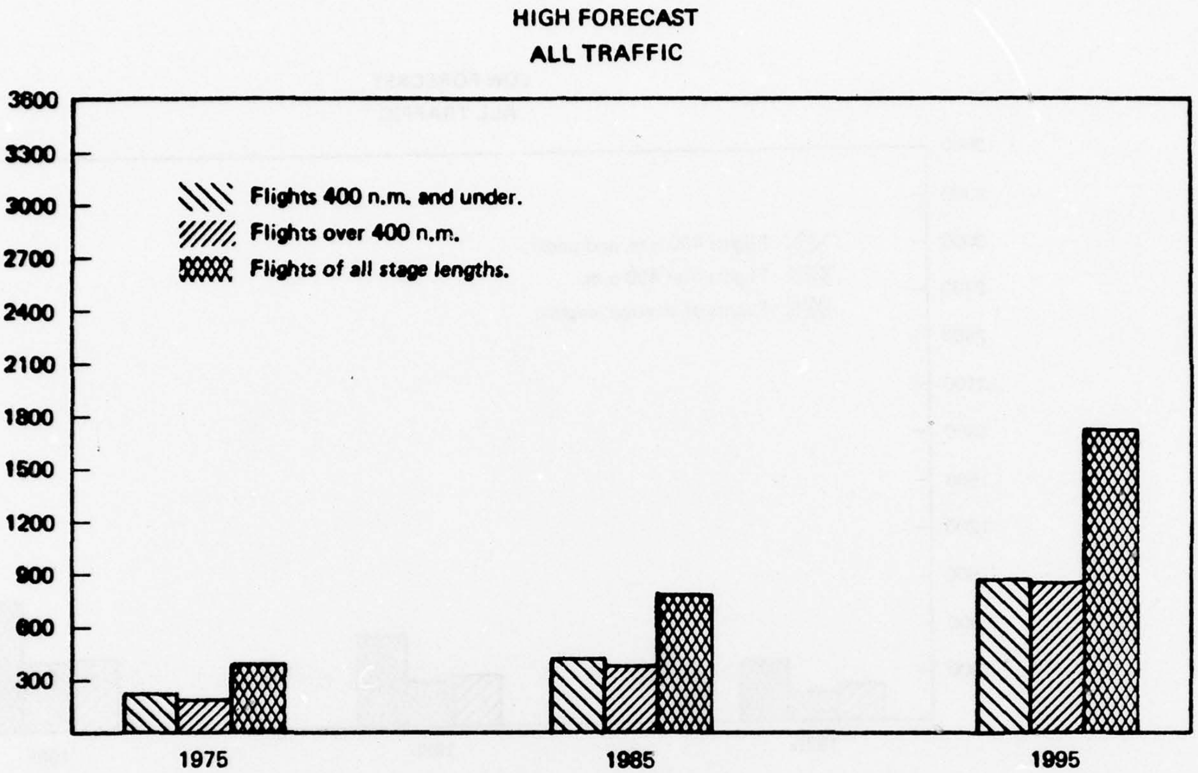
Figures 22 and 23, derived from Table 12, show what happens to peak IACs for short- and long-haul and for "scheduled" and "all traffic" in the forecast years under the low and high forecast assumptions. Figure 22 is based on the low or "pessimistic" forecast and Figure 23 on the "optimistic" or high forecast. Data for 1975 are the same on both Figures 22 and 23 since there are no high and low estimates for 1975. These figures show separately for "scheduled" and for "all traffic" the relative growth in short-and long-haul traffic and traffic for all stage lengths. As does Table 1, these figures demonstrate that for the Pacific basin the long-haul traffic is expected

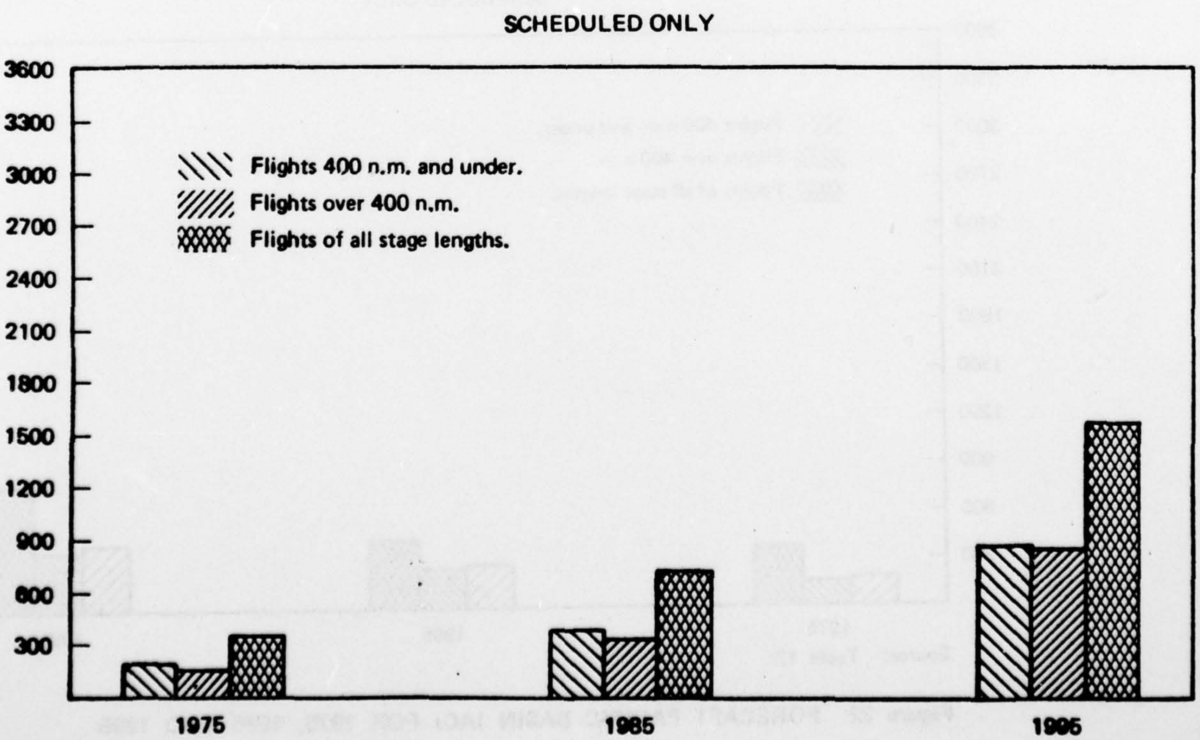




Source: Table 12

Figure 22 FORECAST PACIFIC BASIN IACs FOR 1975, 1985 AND 1995





Source: Table 12

Figure 23 FORECAST PACIFIC BASIN IACs FOR 1975, 1985 AND 1995

to grow faster than the short-haul traffic. Despite this, however, the short-haul traffic peak IACs remain greater than long-haul throughout the forecast period under all circumstances.

2. IACs by IAC Area and Time of Day

Like the Indian basin, the Pacific was subdivided into rectangles (called IAC areas) related to actual or anticipated traffic flow patterns rather than attempting to approximate FIRs. Figure 24 shows the location of the IAC areas in relation to the FIRs. The exact descriptions of the 11 Pacific IAC areas are shown in Table 13.

The IAC area boundaries, in many cases, run through the airports serving major traffic centers permitting the independent examination of different traffic flows to and from these centers. Thus, the border between Pacific IAC areas P-1 and P-2 goes through the Tokyo Airport permitting separate examinations of traffic flows east and west of Tokyo. Hawaii rests on the borders of three IAC areas so that the peaking of traffic Hawaii South, Hawaii West and Hawaii East can be examined somewhat independently.

The peak IAC for the Pacific Ocean basin occurs from 0100 to 0400 Greenwich time, as presented in Table 14. This is roughly 1500 to 1800 local time in Hawaii. As in other basins analyzed in this research, the local daytime hours are the busiest periods of aircraft activity.

Table 14 presents a base year representation of peak IACs by IAC area. Calculations are presented for the 1975 scheduled traffic for all stage lengths, for stage lengths 400 nautical miles and less, and for flights with stage lengths over 400 nautical miles. While the 11 IAC areas used to subdivide the Pacific Ocean basin are not of equal size (comparisons of relative IAC levels therefore

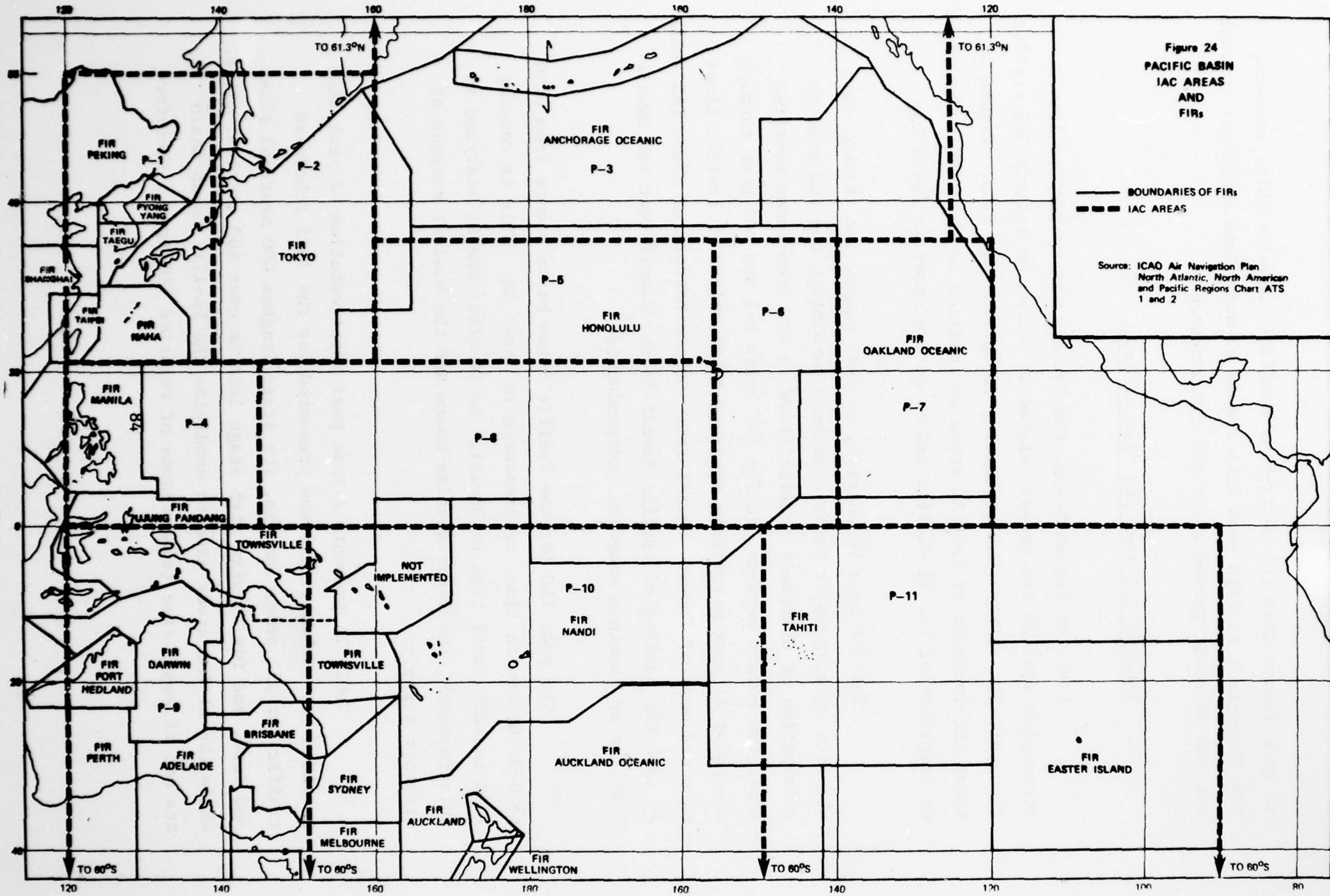


Figure 24
PACIFIC BASIN
IAC AREAS
AND
FIRs

Source: ICAO Air Navigation Plan North Atlantic, North American and Pacific Regions Chart ATS 1 and 2

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FORECAST AND ANALYSIS OF INTERNATIONAL AIR TRAFFIC IN RELATION --ETC(U)
DEC 77 R POZDENA, J GORHAM, D GROSS, D YEE DOT-FA75WA-3574-1

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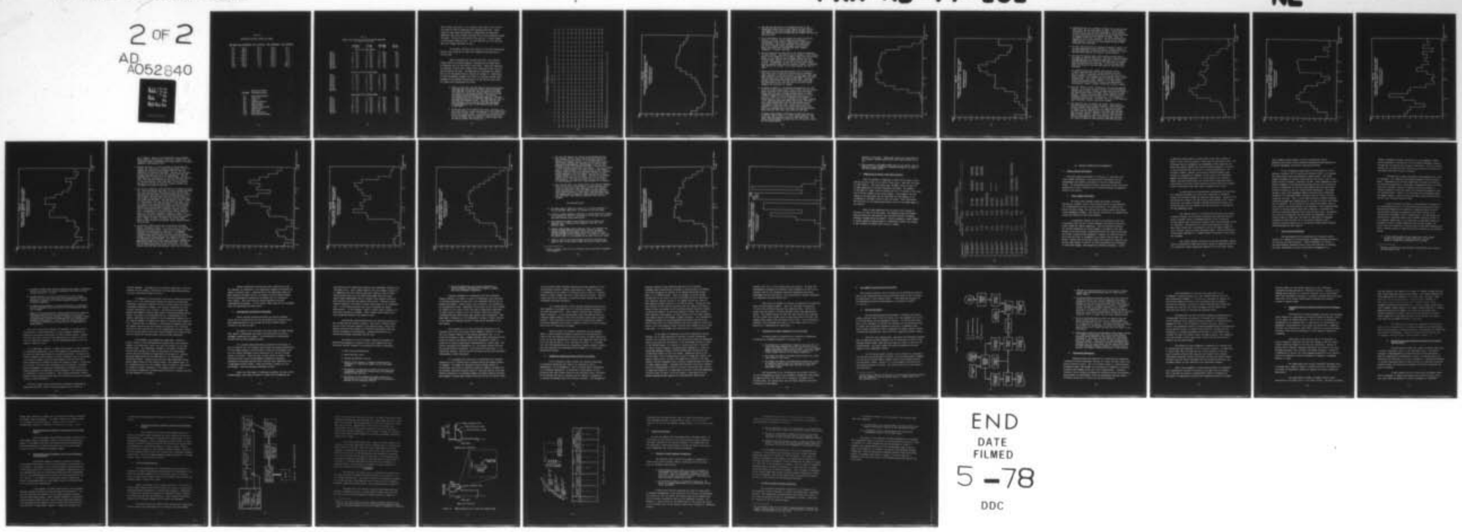

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Table 13

LOCATION OF PACIFIC BASIN IAC AREAS

IAC Area	N.E. Longitude	N.E. Latitude	S.W. Longitude	S.W. Latitude
P-1	139.8	55.0	120.0	21.3
P-2	160.0	55.0	139.8	21.3
P-3	-125.0	61.3	160.0	35.5
P-4	144.8	21.3	120.0	0.0
P-5	-157.9	35.5	160.0	21.3
P-6	-140.0	35.5	-157.9	0.0
P-7	-120.0	35.5	-140.0	0.0
P-8	-157.9	21.3	144.8	0.0
P-9	151.2	0.0	120.0	-60.0
P-10	-149.6	0.0	151.2	-60.0
P-11	-90.0	0.0	-149.6	-60.0

IAC Area	Major Location(s) Included in Area
P-1	Japan/Korea/Taiwan
P-2	Japan East
P-3	Alaska
P-4	Guam/Philippines
P-5	Hawaii/Japan
P-6	Hawaii/Conus
P-7	Oakland (California)
P-8	Hawaii/Guam
P-9	Australia
P-10	New Zealand/Fiji
P-11	Tahiti/Easter Island

Table 14

PEAK IAC CALCULATIONS BY IAC AREA FOR THE PACIFIC OCEAN BASIN:
1975 SCHEDULED TRAFFIC ONLY

	Busy Entry Hr	Entries	Busy OPS Hr	OPS	**Busy Flite Hr**	**Fhrs**	**IAC For Busy Fhr**
			Flights of All Stage Lengths				
Basin	1.	356.0	1.	331.1	3.	334.2	360.0
IAC P-1	1.	98.0	9.	92.5	3.	104.9	113.0
IAC P-2	5.	30.0	5.	24.5	7.	30.8	37.0
IAC P-3	20.	38.0	20.	40.5	19.	48.0	55.0
IAC P-4	1.	28.0	1.	23.0	1.	19.5	22.0
IAC P-5	22.	10.0	22.	11.0	4.	11.0	13.0
IAC P-6	20.	38.0	2.	36.5	24.	33.3	41.0
IAC P-7	22.	11.0	22.	10.0	23.	18.0	19.0
IAC P-8	1.	4.0	19.	4.0	17.	6.4	7.0
IAC P-9	1.	95.0	1.	90.5	2.	77.1	86.0
IAC P-10	2.	68.0	22.	64.5	22.	49.9	52.0
IAC P-11	24.	12.0	24.	11.5	2.	1.9	3.0
			Flights of 400 Nautical Miles or Less				
Basin	1.	269.0	1.	258.5	1.	184.6	198.0
IAC P-1	2.	62.0	8.	59.0	8.	53.8	57.0
IAC P-2	5.	12.0	5.	10.5	5.	10.1	12.0
IAC P-3	19.	29.0	19.	27.5	19.	16.7	21.0
IAC P-4	1.	19.0	3.	16.5	4.	14.2	16.0
IAC P-5	21.	8.0	22.	8.5	22.	3.1	5.0
IAC P-6	4.	25.0	20.	23.5	20.	8.5	12.0
IAC P-7	0.	0.0	0.	0.	0.	0.0	0.0
IAC P-8	6.	2.0	6.	2.0	6.	1.1	2.0
IAC P-9	1.	80.0	1.	77.0	2.	57.6	64.0
IAC P-10	2.	57.0	2.	55.0	1.	36.7	44.0
IAC P-11	3.	9.0	24.	8.5	4.	0.9	2.0
			Flights Longer than 400 Nautical Miles				
Basin	1.	87.0	1.	72.5	3.	162.0	167.0
IAC P-1	9.	43.0	5.	37.5	4.	53.2	58.0
IAC P-2	5.	18.0	5.	14.0	7.	22.7	26.0
IAC P-3	3.	16.0	3.	16.0	19.	31.3	34.0
IAC P-4	8.	10.0	10.	8.5	9.	8.7	10.0
IAC P-5	1.	3.0	21.	3.0	16.	10.2	11.0
IAC P-6	20.	15.0	2.	14.5	24.	26.2	29.0
IAC P-7	22.	11.0	22.	10.0	23.	18.0	19.0
IAC P-8	10.	4.0	19.	4.0	17.	6.4	7.0
IAC P-9	4.	21.0	2.	17.0	5.	26.8	29.0
IAC P-10	24.	14.0	24.	12.5	25.	17.6	21.0
IAC P-11	1.	4.0	1.	5.0	1.	1.1	2.0

must be made cautiously), it is apparent from Table 14 that Pacific IAC areas P-1 and P-9 experienced the greatest peak IACs. These areas are over Japan and Australia, respectively, and therefore experience more local traffic than many of the other primarily oceanic IAC areas. Of the 113 peak IACs for IAC area P-1, 57 were flights of 400 nautical miles or less. For IAC area P-9, 64 of its 86 peak IACs were flights 400 miles or less.

In contrast, IAC area P-11, which is in the far southeastern Pacific, had a peak IAC of only three flights in the busy hour of the busy day.

Table 15 presents for the base year 1975, for scheduled traffic only of all stage lengths, a distribution of flight hours by Greenwich hour for the Pacific Ocean basin. These data represent the fraction of total daily flight hours occurring at every hour of the busy day by IAC area. The same data are represented in graphic form in the histograms shown in Figures 25 through 36. Examination of these histograms, together with Table 14, provides further understanding of the peaking characteristics of the Pacific Ocean basin as a whole and of particular IAC areas.

- Table 14 shows that the peak IACs for each of the Pacific IAC areas all occur within an 8-hour period extending from 2400 GMT to 0700 GMT. Thus the peak for the basin as a whole is a broad peak between these hours falling off sharply during subsequent hours. The graphic representation of this is shown in Figure 25. The peak is a plateau running from 2400 GMT (1400 Honolulu time) to 0700 GMT (2200 Honolulu time). The high peak for the area actually covers a span of three hours extending from 1500 Honolulu time to 1800 Honolulu time (0100 to 0400 GMT).

- As was the case in the Indian Ocean basin, individual IAC area peaks reflect a higher percentage of total flight hours than does the basin peak. In contrast to the Indian Ocean basin, the system peak for flights of 400 nautical miles or less is higher than the peak for flights longer than 400 nautical miles (198 versus 167).

Table 15

DISTRIBUTION OF FLIGHT HOURS BY GREENWICH HOUR FOR THE PACIFIC OCEAN BASIN
(1975 scheduled traffic only-all stage lengths)

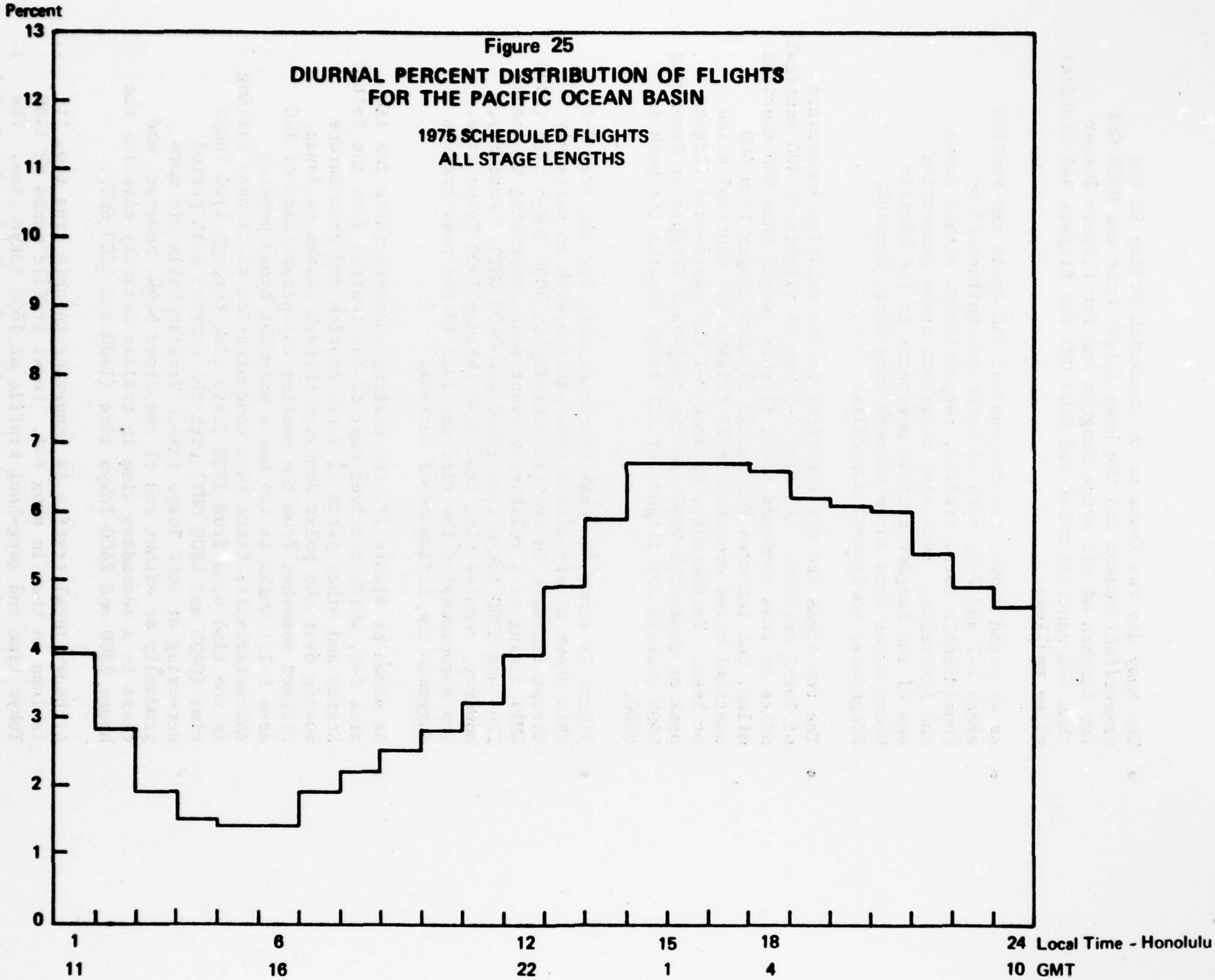
	Greenwich Hour																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Basin	.067	.067	.067	.066	.062	.061	.060	.054	.049	.045	.039	.028	.019	.015	.014	.014	.019	.022	.025	.028	.032	.039	.049	.059
IAC P-1	.069	.080	.084	.084	.074	.078	.080	.078	.077	.078	.068	.043	.019	.0040	.000	.000	.000	.000	.000	.001	.002	.004	.025	.051
IAC P-2	.059	.057	.058	.057	.072	.085	.088	.072	.057	.051	.036	.031	.028	.052	.051	.022	.001	.003	.007	.014	.022	.017	.022	.039
IAC P-3	.051	.047	.057	.050	.046	.031	.025	.011	.007	.010	.016	.020	.022	.023	.027	.044	.065	.076	.082	.067	.053	.051	.056	.062
IAC P-4	.086	.069	.074	.067	.055	.069	.072	.079	.085	.072	.042	.019	.019	.014	.010	.013	.009	.003	.001	.004	.004	.011	.060	.062
IAC P-5	.069	.071	.072	.074	.040	.017	.017	.025	.013	.015	.017	.017	.035	.042	.047	.068	.074	.068	.060	.058	.036	.023	.013	.029
IAC P-6	.081	.063	.050	.038	.034	.033	.043	.025	.021	.033	.028	.023	.013	.025	.022	.019	.025	.026	.041	.073	.073	.067	.063	.081
IAC P-7	.044	.069	.063	.083	.062	.048	.032	.024	.017	.000	.015	.029	.032	.014	.004	.004	.015	.046	.049	.044	.060	.084	.090	.067
IAC P-8	.048	.037	.026	.033	.028	.036	.017	.036	.025	.028	.070	.065	.060	.033	.051	.073	.099	.064	.060	.031	.016	.020	.016	.029
IAC P-9	.069	.077	.064	.069	.071	.072	.069	.062	.052	.042	.034	.025	.015	.006	.004	.004	.014	.020	.020	.020	.023	.052	.060	.040
IAC P-10	.067	.056	.068	.062	.060	.060	.052	.054	.049	.037	.028	.018	.013	.012	.011	.011	.011	.012	.017	.034	.060	.070	.069	.069
IAC P-11	.193	.216	.034	.125	.034	.0110	.0000	.0000	.0000	.0000	.000	0.0000	.0000	.0000	.0000	.0000	.000	.011	.045	.091	.034	.102	.1020	.000

NOTE: These figures represent the fraction of total daily flight hours that occur each hour of the busy day by IAC area.

Figure 25

DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR THE PACIFIC OCEAN BASIN

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS



- The busy day was found to be Greenwich Friday in the summer/fall season and the busy flight hour was 0300 GMT for flights of all stage lengths and for flights longer than 400 nautical miles and 0100 GMT for flights 400 nautical miles and less.

- As we noted above, the two busiest IAC areas are Pacific areas P-1 and P-9, both of which are influenced by considerable local traffic, respectively, within Japan and Australia. Both also represent areas generating one of the largest traffic movements in the Pacific Ocean areas from Japan through Hong Kong, Bangkok, Singapore, to Sydney, Australia.

- The two areas are not identical in the relative importance of local traffic. IAC area P-9 has 64 flights of 400 nautical miles or less compared to 21 flights longer than 400 nautical miles, but IAC area P-1 has 58 flights longer than 400 nautical miles compared to 57 flights 400 nautical miles or less. Furthermore, in area P-1 the short-haul flights peak at Greenwich 0800 and the long-haul flights at Greenwich 0400 whereas for flights of all stage lengths the peak is 0300.

- Figure 26 shows the peak characteristic for IAC area P-1. This shows a very distinctive pattern with an extremely abrupt increase in traffic activity at 0800 Tokyo time (2300 GMT) rising to a relatively blunt peak comprising the hours 1200 and 1300 Tokyo time (0300 and 0400 GMT). Activity, however, remains high from 1100 through 1900 Tokyo time. The abruptness of the rise and fall in the peak traffic suggests the influence of curfews.

- As shown by Figure 27, the peaking characteristic for IAC area P-2, which receives most of the traffic from the United States and other parts of North America and from Europe moving over the polar routings through Alaska to Japan, differs somewhat from the peaking characteristics of IAC area P-1. While it too has a somewhat broad peaking characteristic, there is a concentration of flights falling in the time band from 1400 Tokyo time through 1700 Tokyo time (0400 and 0800 GMT) with the extreme peak period occurring at 1600 Tokyo time. Traffic falls off more gradually at either end of the broad peak, however, and there is a secondary rise in traffic activity covering the hours 2300 and 2400 Tokyo time (1400 and 1500 GMT).

  Although local traffic is important in this area too, it is less so than in area P-1. Local traffic peaks at 1400 Tokyo time and long-haul traffic at 1600 Tokyo time. The latter peak determines the busy hour for the area as a whole for all stage lengths.

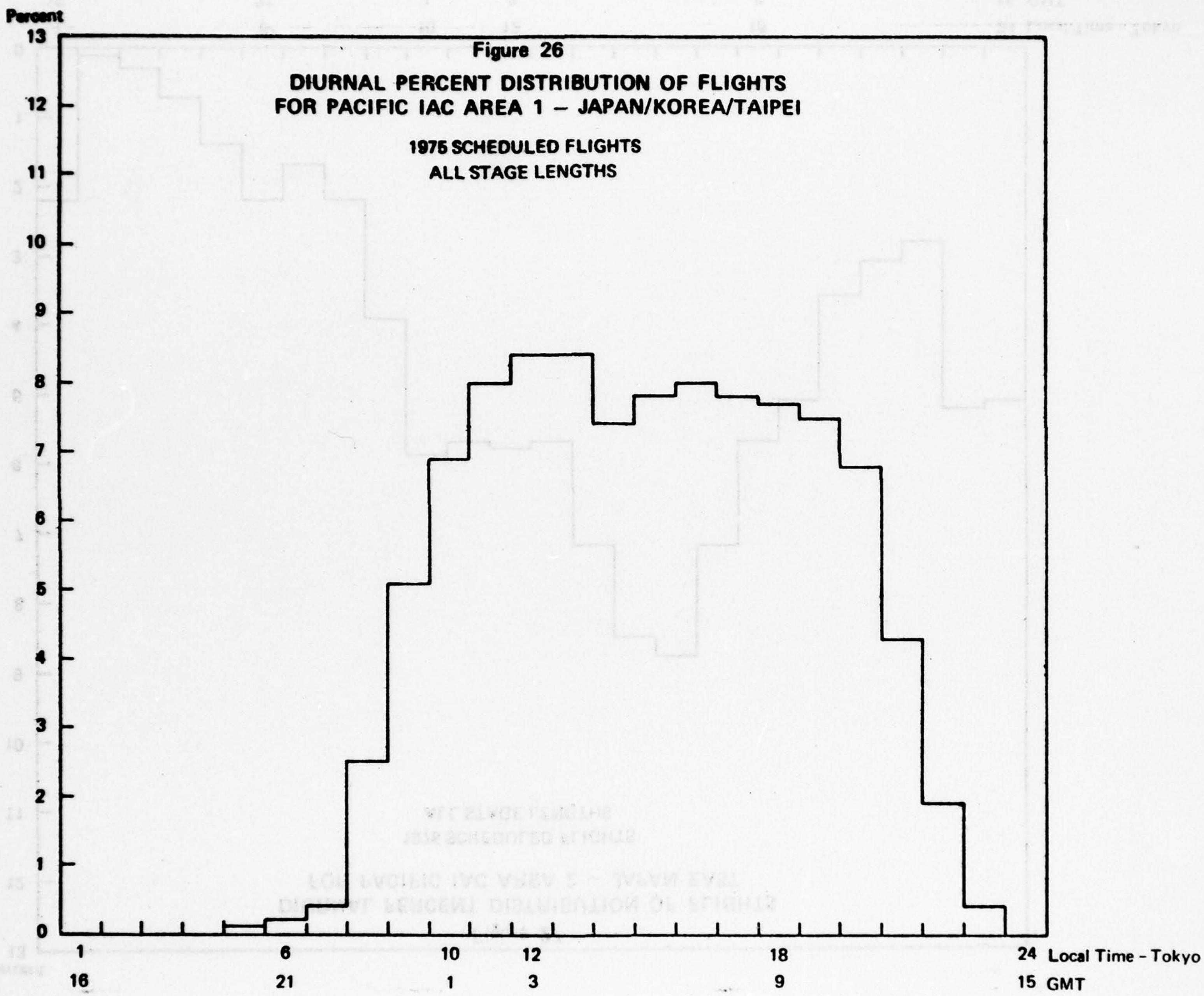


Figure 26

DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR PACIFIC IAC AREA 1 – JAPAN/KOREA/TAIPEI

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

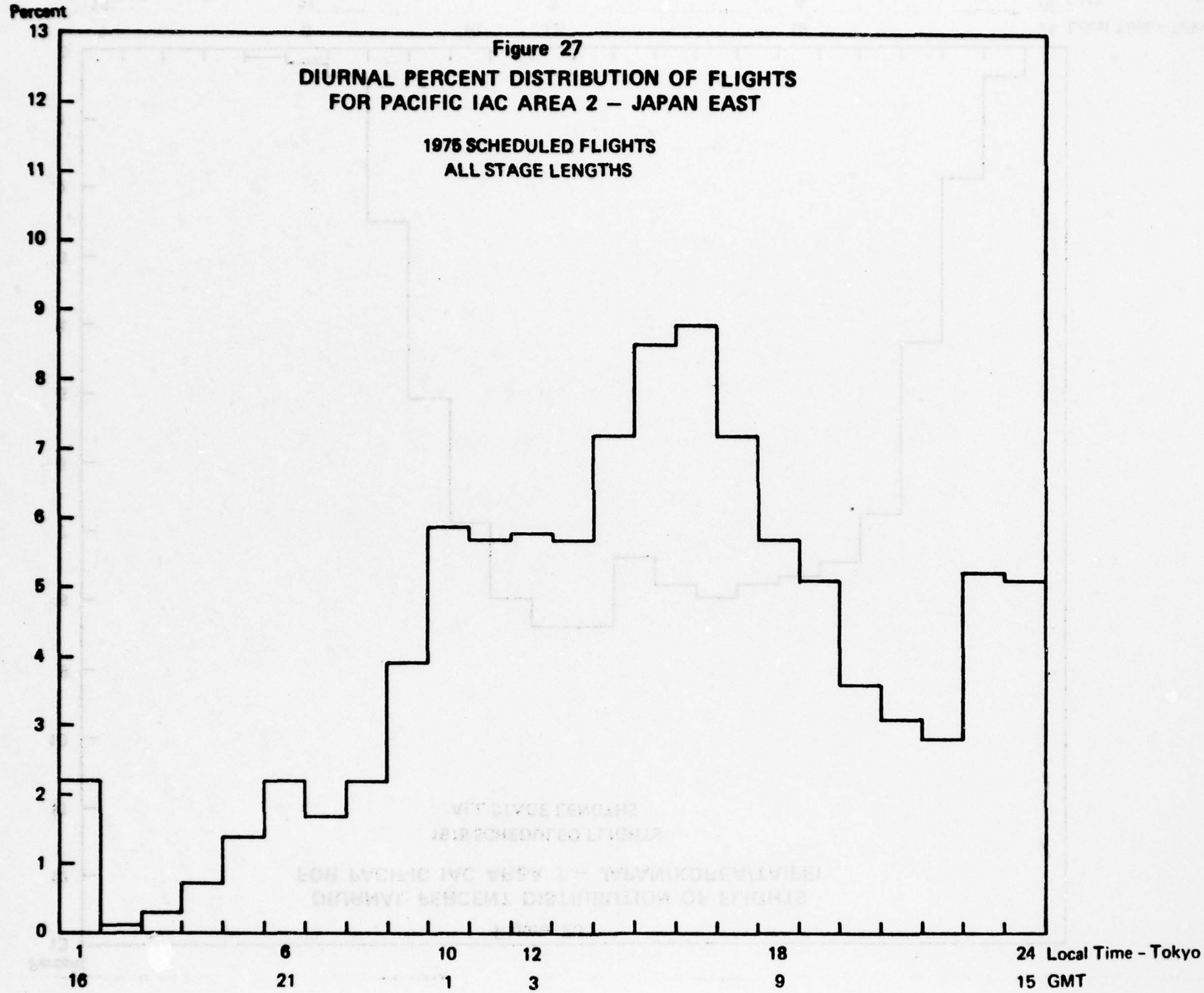


Figure 27
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR PACIFIC IAC AREA 2 – JAPAN EAST

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

- Pacific IAC area P-3, as shown in Figure 28, is much broader than either the two areas based on Tokyo. Local traffic is important in this IAC area, although it is the stopoff point on traffic moving from eastern North America and Europe to Japan via polar or trans-Canada routings. There are 21 flights of 400 miles or less in the 1975 peak busy hour compared to 34 of over 400 miles. The short- and long-haul peaks, however, coincide with those peaks falling at 0900 Anchorage time (1900 GMT).

- The next four IAC areas are related to Honolulu traffic, two of them representing areas traversed by traffic moving to and from areas west of Honolulu and two traversed by traffic moving between Honolulu and points in North America.

- IAC area P-5 includes most traffic moving between Hawaii and Japan as shown by Figure 29. This has a distinct bimodal peaking pattern with one peak falling within the hours 0600 and 0800 Honolulu time (1600 and 1800 GMT) with the highest peak falling within the 0700 hour. The second peak falls within the hours of 1500 and 1800 Honolulu time (0100 and 0400 GMT).

  The peak for short-haul traffic (400 nautical miles or less) comprises only five flight movements at 1200 Honolulu time, a relatively low period for the area as a whole, compared to 18 flights for the long-haul peak at 0600 Honolulu time. This bimodal peaking therefore can not be attributable to intra-area traffic. It is more likely caused by different peaking in arrival and departures of trans-Pacific traffic, perhaps influenced by Tokyo curfews.

- Area P-8, which is shown in Figure 30, has numerous peaking periods. It contains two major traffic flows from Honolulu through Guam to Japan, Taiwan, and Hong Kong and from Hawaii to the South Pacific points of Samoa, Fiji, Australia and New Zealand. Sydney, Australia-Japan traffic apparently moves through the western part of this area. It is an area of relatively low activity. The peak, which is at 0700 Honolulu time (1700 GMT), contains only seven flights.

- IAC areas P-6 and P-7 include the traffic flows between the Continental United States and Hawaii. Both show fairly distinct bimodal distributions. For IAC area P-6, shown in Figure 31, the peak activity as a whole falls within the hours 1000 and 1500 Honolulu time (2000 and 0100 GMT). This is split, however, between a two-hour peak covering 1000 and 1100 Honolulu time and a two-hour peak covering 1400 and 1500 Honolulu time. The peak IAC for the area as a whole is shown at 1400 Honolulu (2400 GMT) time and

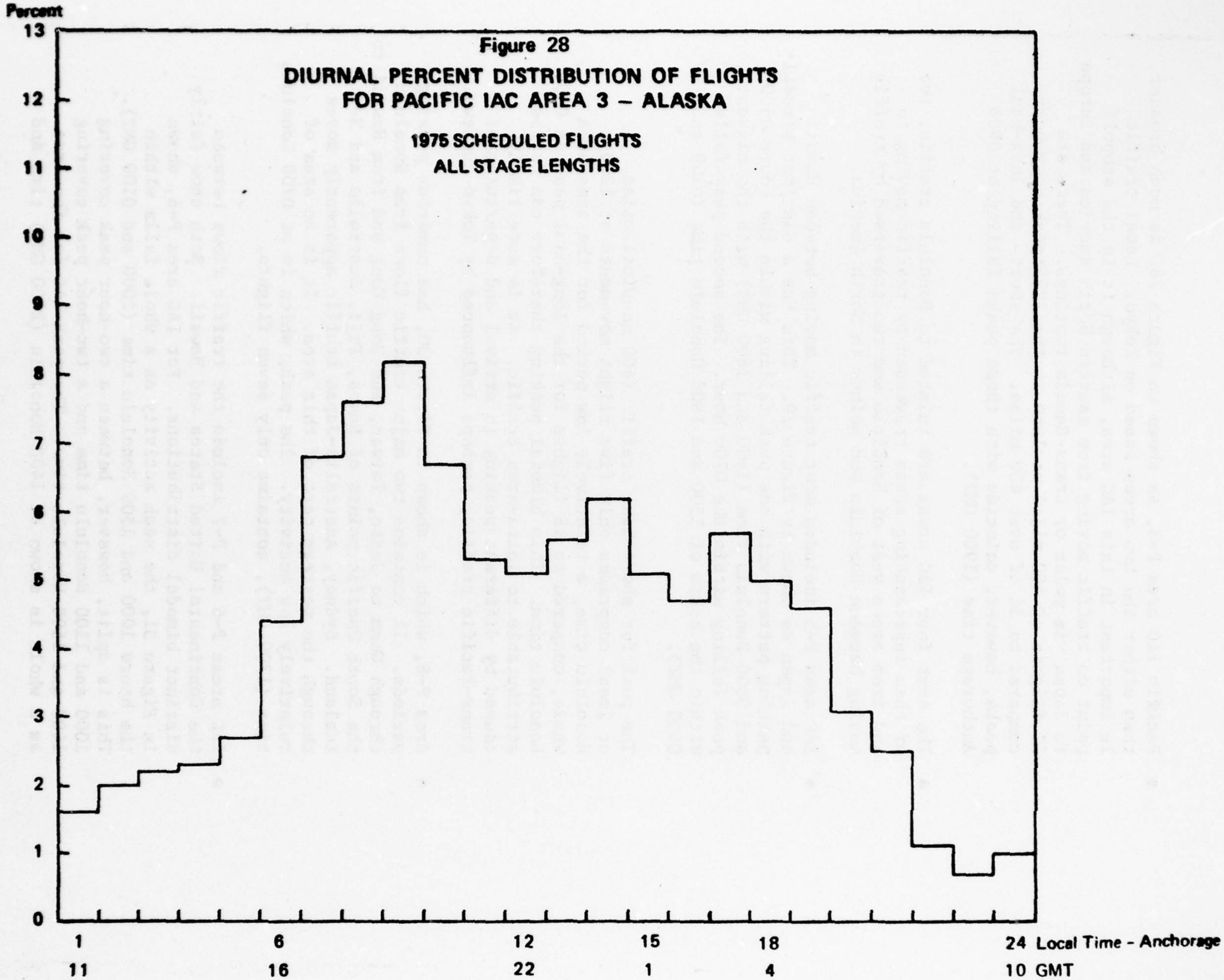


Figure 28
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR PACIFIC IAC AREA 3 – ALASKA
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

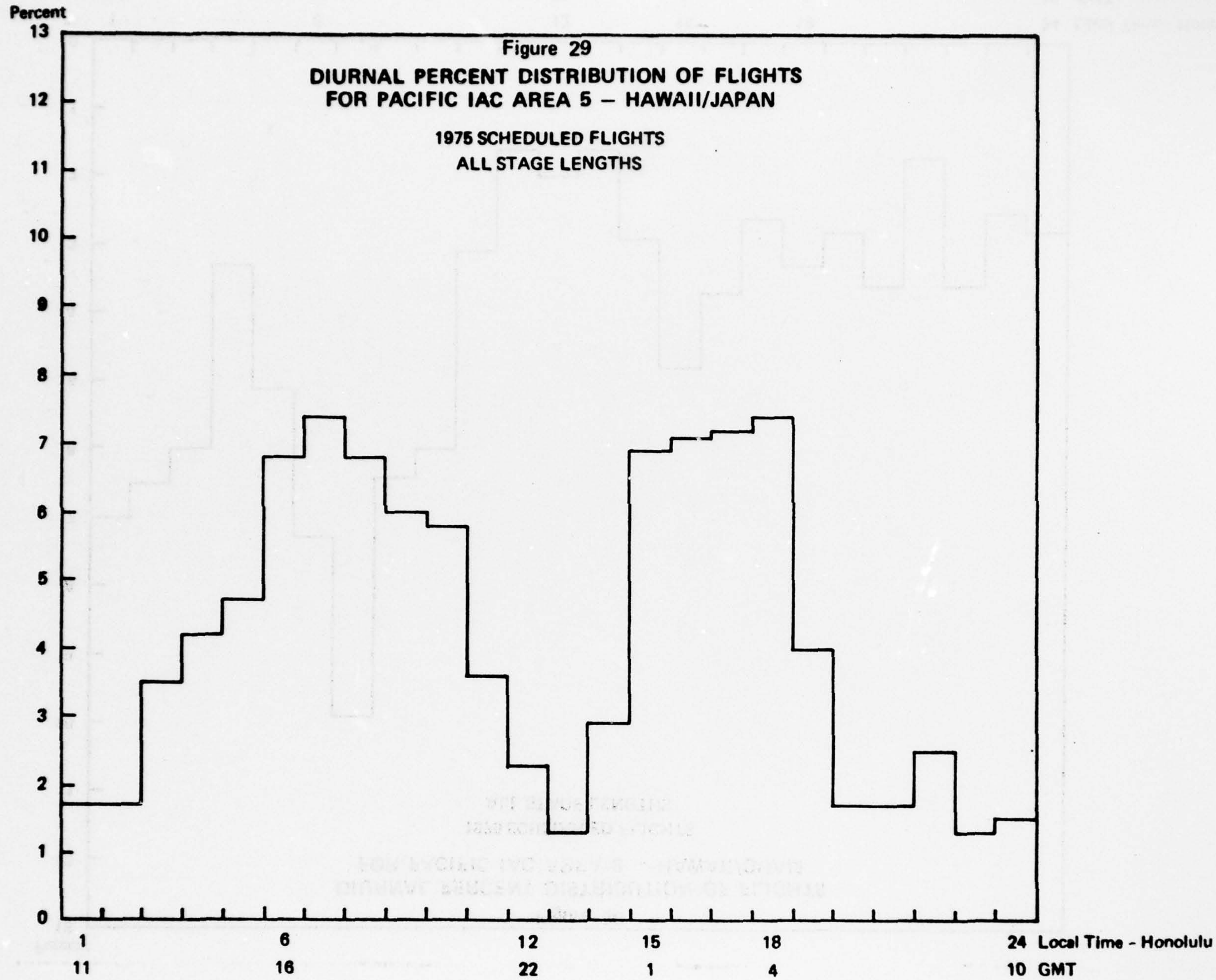


Figure 29

DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR PACIFIC IAC AREA 5 – HAWAII/JAPAN

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

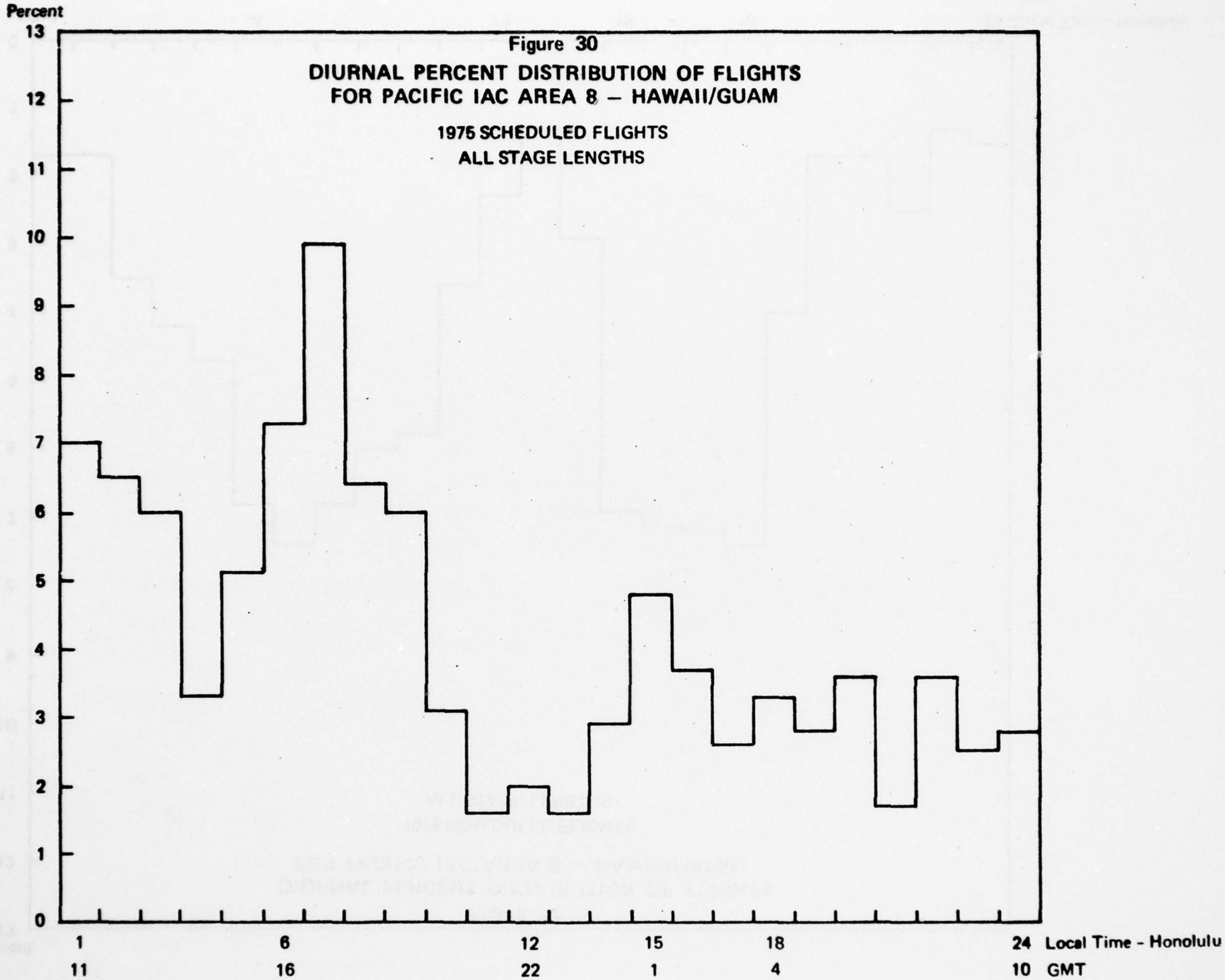


Figure 30
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR PACIFIC IAC AREA 8 – HAWAII/GUAM
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

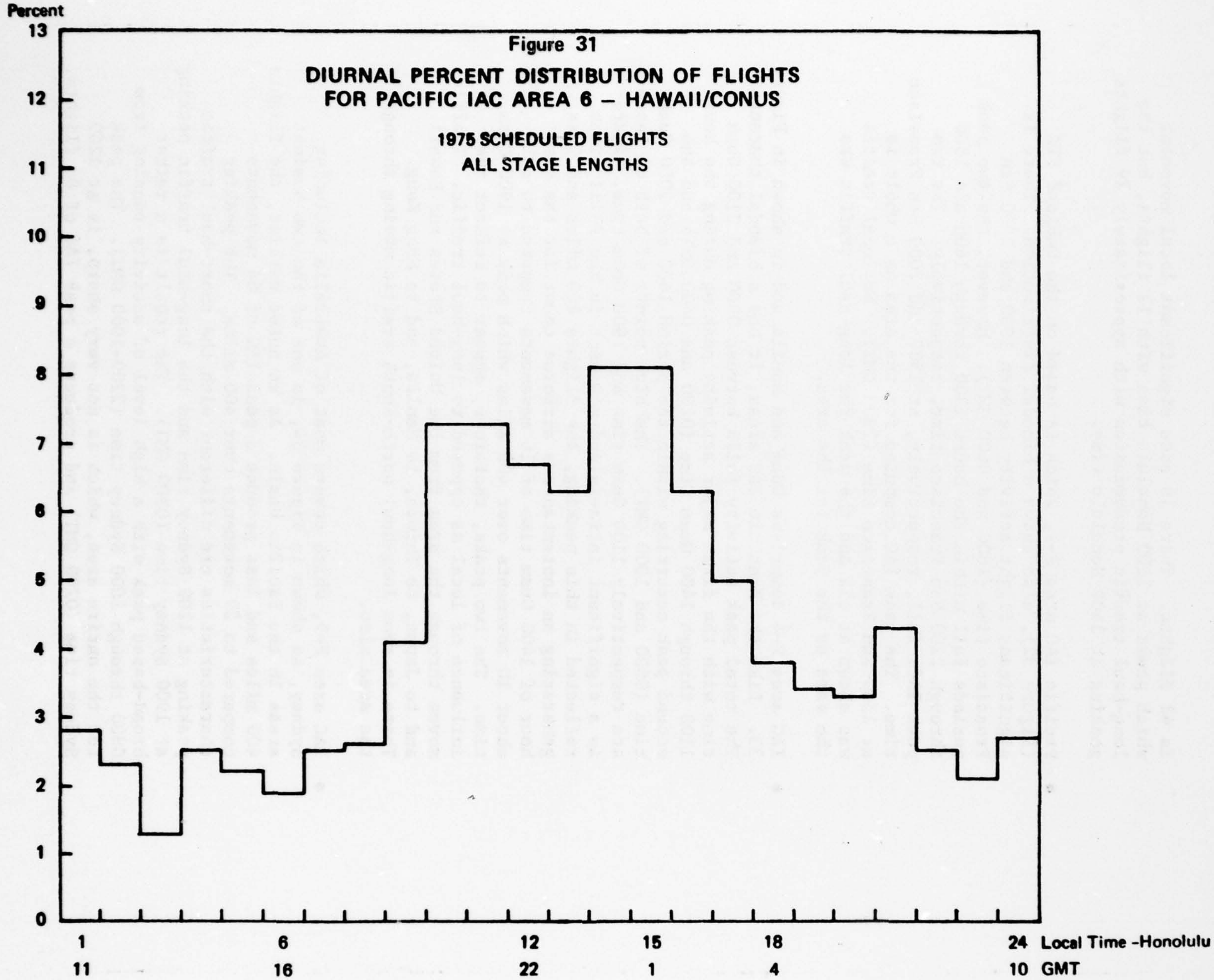


Figure 31

DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR PACIFIC IAC AREA 6 – HAWAII/CONUS

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

is 41 flights. There is some significant local movement which peaks at 1100 Honolulu time with 12 flights, but the long-haul traffic predominates with approximately 29 flights peaking at 1400 Honolulu time.

- Pacific IAC area P-7, which is based on the Oakland FIR (Figure 32), also shows a bimodal distribution. There is significant flight activity between 1000 and 2200 San Francisco time (1800 and 0600 GMT). However, the two peak periods fall within the hours 1300 through 1600 and 1800 through 2200 San Francisco time, respectively. The two peak IACs fall, respectively, at 1500 and 2000 San Francisco time. The peak IAC computed for the area as a whole is at 1500 San Francisco time (2300 GMT). No local traffic was shown at all and the peak for long-haul traffic was the same as the peak for the area.

- IAC area P-4 comprises Guam and Manila and is shown in Figure 33. Like the Honolulu IAC areas, it has a bimodal character. The total peak activity falls between 0900 and 2100 Guam time with the first major activity peaking during the hours 1100 through 1400 Guam time (0100 and 0400 GMT) and the second peak occurring within the period 1600 and 2000 Guam time (0600 and 1000 GMT). The high points of both of these are respectively 1100 Guam time and 1900 Guam time. There is a significant intra-island movement in the Philippines reflected in this peaking, the flights 400 miles and less generating an instantaneous airborne count for the busy hour of 1400 Guam time of 16 movements compared to only about 10 movements over 400 miles which peak at 1900 Guam time. The two peaks, therefore, appear to reflect the influence of local as opposed to long-haul traffic. Traffic moves through the area from the United States and Hawaii and to Japan, to Taiwan, to Manila, and to Hong Kong. There is some long-haul north-south traffic moving through the area also.

- IAC area P-9, which covers most of Australia including Sydney, as shown in Figure 34, is one of the two busiest areas in the Pacific basin. As we noted earlier, the flights 400 miles and less produce a peak IAC of 64 movements compared to 29 movements over 400 miles. The peaking characteristics are different with the short-haul traffic peaking at 1200 Sydney time and the long-haul traffic peaking at 1900 Sydney time (0900 GMT). The result is a rather broad-based peak with a high level of activity running from 0800 through 2000 Sydney time (2200-1000 GMT). The peak for the entire area, which is not very sharp, is at 1200 Sydney time (0200 GMT) and produces a peak IAC of 86 flights.

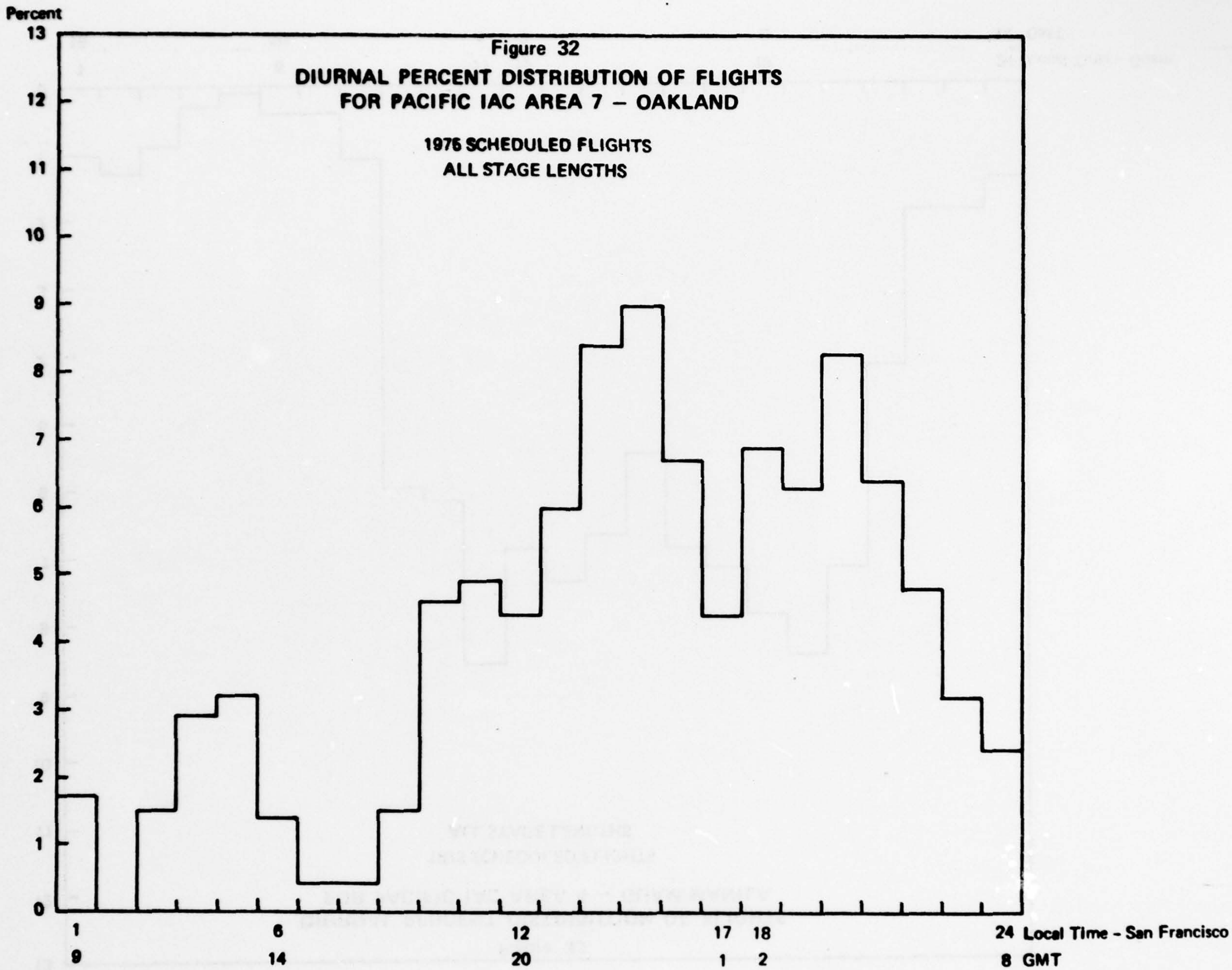
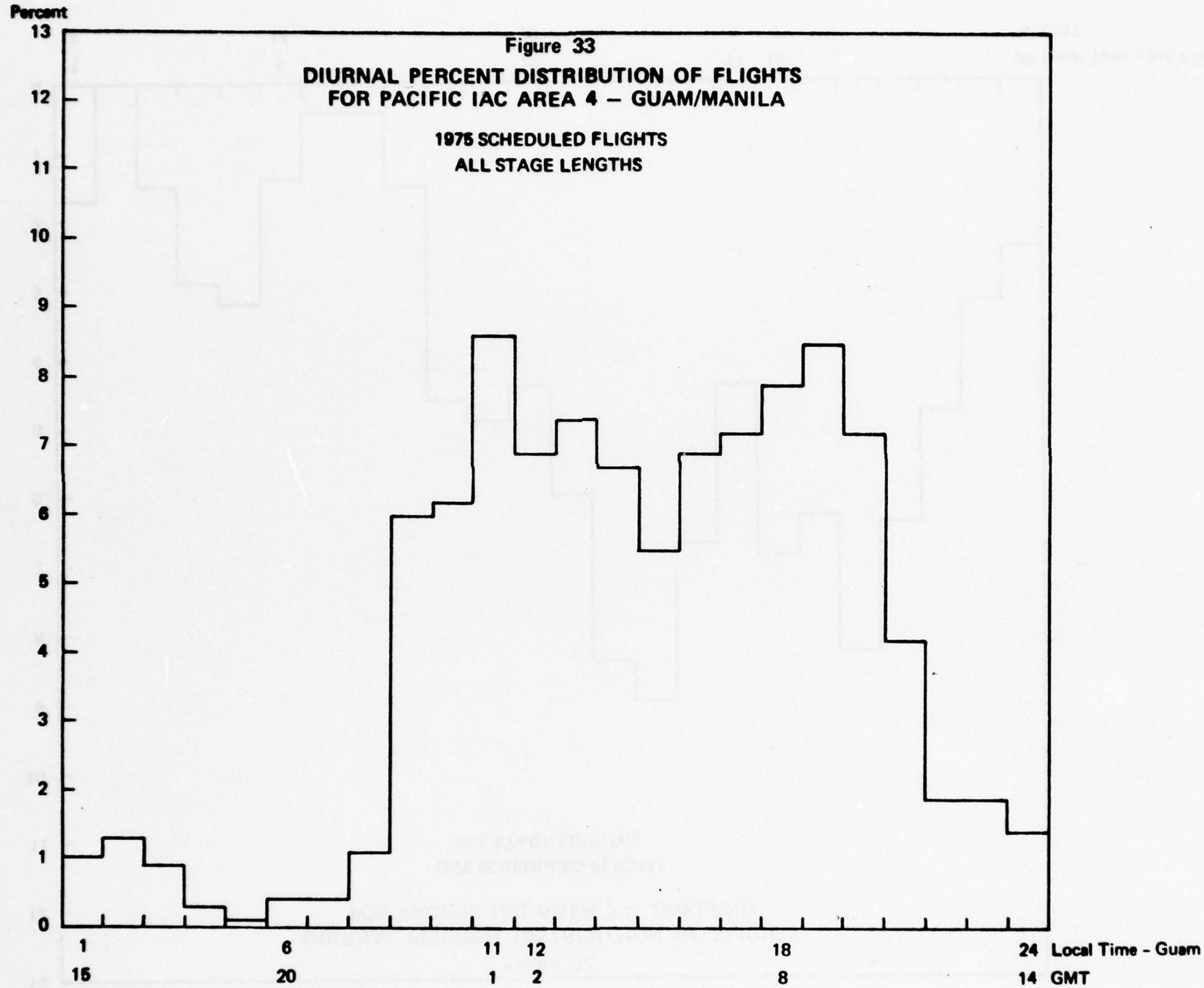


Figure 32
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR PACIFIC IAC AREA 7 – OAKLAND

1976 SCHEDULED FLIGHTS
ALL STAGE LENGTHS


Percent
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Figure 33
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR PACIFIC IAC AREA 4 – GUAM/MANILA
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS
1
6
11
12
18
24 Local Time - Guam
15
20
1
2
8
14 GMT

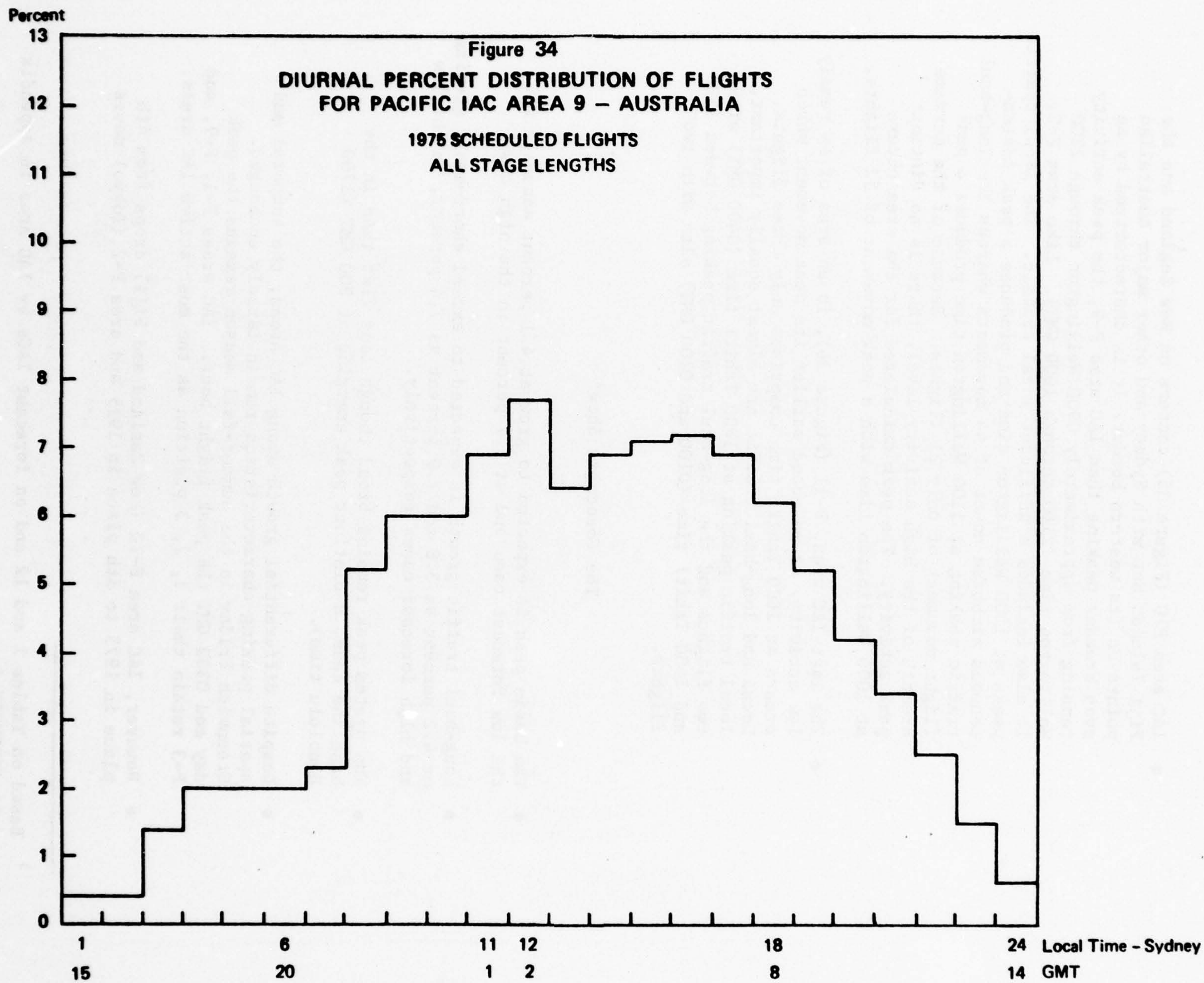


Figure 34
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR PACIFIC IAC AREA 9 – AUSTRALIA
1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS

- IAC area P10 (Figure 35) centers on New Zealand and the Fiji Islands but with Sydney and other major Australian points on its western border. It is characterized by an even broader peaking than IAC area P-9, the peak activity running from approximately 0900 Wellington through 2200 Wellington time (2100 through 1000 GMT). Like area P-9, it also includes significant local traffic. The local traffic peaks at 1300 Wellington time and produces a peak instantaneous airborne count of 44 movements whereas the long-haul traffic peaking at 1100 Wellington time produces a peak flight movement of only 21 flights. Because of the extreme breadth of the high activity level, there is no distinct peak activity. The peak calculated for the area occurs at 1000 Wellington time with a peak movement of 52 flights.

- The last IAC area, P-11 (Figure 36), is an area of extremely low activity. As we noted earlier its peak movement which occurs at 1600 Tahiti time comprises only three flights. Local and long-haul traffic are almost equally important, local traffic peaking at 1800 Tahiti time (0400 GMT) with two flights and the long-haul traffic peaking between 1500 and 1600 Tahiti time (0100 and 0200 GMT) also with two flights.

The Forecasts Show[1]

- The basin peak is expected to grow at 4.1 percent annually in the low forecast case and at 7.7 percent in the high case.

- Long-haul traffic growth is expected to exceed short-haul, growing at 4.2 percent vs 3.8 and 7.9 percent vs 7.4 percent, in the low and high forecast cases respectively.

- The system peak remains broad though less flat than in the baseline case, a distinct peak emerging at 300 GMT (1700 Honolulu time).

- Despite differential growth among IAC areas, the temporal and spatial peaking characteristics remain largely unchanged. Greenwich Friday in the summer-fall season remains the peak day and 0300 GMT the peak flight hour. IAC areas P-1, P-9, and P-3 retain their 1, 2, 3 position as the most active IAC areas.

- However, IAC area P-10 (New Zealand and Fiji) drops from 4th place in 1975 to 5th place in 1995 and area P-2 (Tokyo) moves

[1] Based on Tables 1 and 12 and on forecast IACs by IAC area in Appendix D to APPENDIX I.

Figure 35
DIURNAL PERCENT DISTRIBUTION OF FLIGHTS
FOR PACIFIC IAC AREA 10 – NEW ZEALAND/FIJI

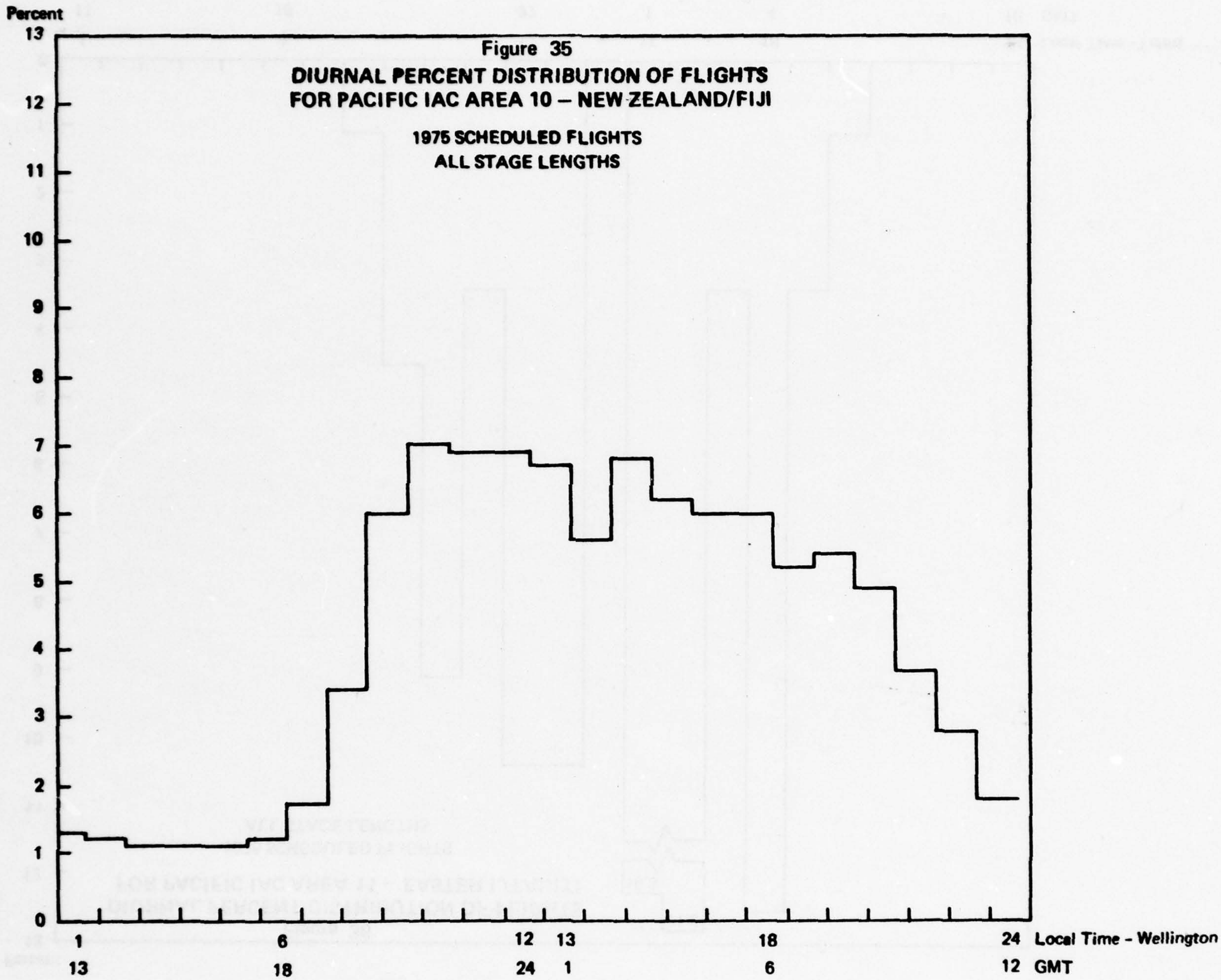
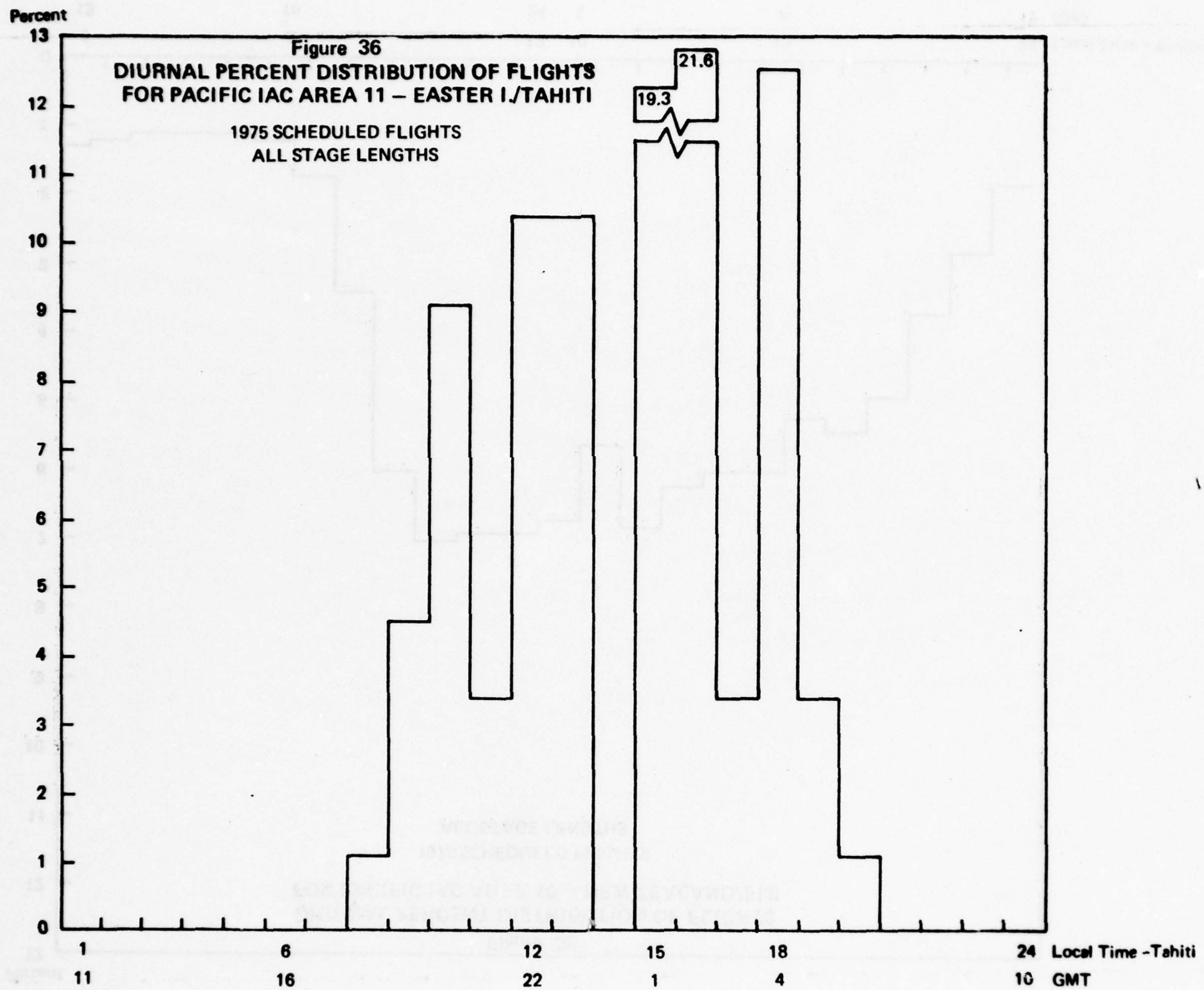


Figure 36

DIURNAL PERCENT DISTRIBUTION OF FLIGHTS FOR PACIFIC IAC AREA 11 – EASTER I./TAHITI

1975 SCHEDULED FLIGHTS
ALL STAGE LENGTHS



from 6th to 4th place. Hawaii East (area P-6) drops from 5th to 7th place, whereas Guam, Manila (P-4) moves up from 7th to 6th.

- Most notable is the higher growth rate in the Pacific than the Atlantic traffic--especially long-haul--though not as high as the Indian basin growth.

3. Composition of Pacific Ocean Basin Activity

Table 16 presents a comparison of peak IACs for major routes and for all air routes in the Pacific Ocean basin. Peak IACs are based on "all traffic". The table shows that the major routes account for a large proportion of activity throughout the basin. For example, in IAC area P-2, major routes accounted for 82 or 71 percent of the total IAC of 116 for flights of all stage lengths. This suggests that the timing of the basin peak and the individual IAC peak appears to be determined by the major routes in most IAC areas. This relationship was also found in the Indian Ocean basin, yet not to the same degree in the Pacific.

Table 16 also identifies the top three routes (ranked by entries) for each of the IAC areas. The dominant routes are between Japan and Australia and between Japan and North America, including movements through Alaska and Hawaii. Traffic stopping at either Hawaii or Alaska appears as Hawaii/Japan or Alaska/Japan traffic even though it may originate in CONUS United States or Europe.

Table 16

COMPARISON OF 1975 PEAK IACs FOR MAJOR ROUTES AND ALL AIR ROUTES IN THE PACIFIC OCEAN BASIN (ALL TRAFFIC)

IAC AREA/STAGE LENGTH	PEAK IAC AND HOUR (GMT)		MAJOR ROUTES*		
	MAJOR ROUTES ONLY	ALL ROUTES	1	2	3
Basin (All Areas)					
• All stage lengths	221 (2)	396 (3)			
• Over 400 N.M.	92 (4)	191 (3)			
P-1					
• All stage lengths	82 (3)	116 (3)	Intra Japan	Japan/Hong Kong	Alaska/Japan
• Over 400 N.M.	35 (3)	60 (4)	Intra Japan	Japan/Hong Kong	Alaska/Japan
P-2					
• All stage lengths	33 (6)	42 (7)	Intra Japan	Alaska/Japan	Hawaii/Japan
• Over 400 N.M.	23 (7)	31 (7)	Intra Japan	Alaska/Japan	Hawaii/Jappan
P-3					
• All stage lengths	44 (19)	71 (19)	Intra Alaska	Alaska/Japan	Alaska/Hawaii
• Over 400 N.M.	15 (19)	42 (19)	Intra Alaska	Alaska/Japan	Alaska/Hawaii
P-4					
• All stage lengths	3 (8)	23 (1)	Australia/Hong Kong	-	-
• Over 400 N.M.	3 (8)	10 (9)	Australia/Hong Kong	-	-
P-5					
• All stage lengths	16 (4)	17 (4)	Intra Hawaii	Hawaii/Japan	-
• Over 400 N.M.	10 (4)	14 (17)	Hawaii/Japan	-	-
P-6					
• All stage lengths	49 (24)	57 (24)	Intra Hawaii	Hawaii/U.S.	-
• Over 400 N.M.	35 (24)	41 (24)	Hawaii/U.S.	-	-
P-7					
• All stage lengths	24 (23)	26 (23)	Hawaii/U.S.	-	-
• Over 400 N.M.	24 (23)	26 (23)	Hawaii/U.S.	-	-
P-8					
• All stage lengths	1 (17)	7 (17)	Japan/Australia	-	-
• Over 400 N.M.	1 (17)	7 (17)	Japan/Australia	-	-
P-9					
• All stage lengths	67 (7)	89 (2)	Intra Australia	Australia/Singapore	Thailand/Australia
• Over 400 N.M.	23 (7)	30 (5)	Intra Australia	Australia/Singapore	Thailand/Australia
P-10					
• All stage lengths	24 (9)	54 (22)	Intra Australia	Singapore/Australia	-
• Over 400 N.M.	8 (23)	22 (23)	Intra Australia	Singapore/Australia	-
P-11					
• All stage lengths	6 (4)	4 (2)	-	-	-
• Over 400 N.M.	3 (22)	4 (2)	-	-	-

* Ranked by number of daily entries in descending order
\- No major routes identified

III FORECAST ASSUMPTIONS AND METHODOLOGY

A. Future Aviation Environment

The future market environment of aviation is a function of the travel demand environment, the institutional environment, and the technological and resource environment of the air transportation market. Our forecasting system has been constructed so that alternative assumptions of these attributes may be directly rendered as parametric inputs to the system.

1. Travel Demand Environment

As recent world economic events have shown, the macro-influence of economic, social, and political forces on the demand for air transportation services is quite pronounced. As political and social alliances change, the affinity felt between various world population subsegments changes. This affects the quantity of transportation interaction observed in particular markets.

A fundamental problem that had to be resolved in this IAC forecasting effort was the relative emphasis that should be placed on traffic flows and traffic generation. IACs are spacially oriented. The aircraft population of a given segment of airspace at any time depends on how much traffic is generated between the regions that might use flights traversing this geographic airspace, the hours and days at which they are flown to accommodate this traffic, and how they are routed. Charter and not-for-hire flights have definitive departure and arrival times subject to many of the same determinants and constraints as route-type flights, even though more randomly determined. Traffic

is generated between pairs of points based on the need or desire of people to have people or goods at other places at particular times. The influences that are fundamental in explaining traffic generation are often quite market specific and require detailed analysis of intercity or area interaction and attraction for precise determination. The routing of traffic, however, particularly overocean between large regions, is determined by nonmarket factors such as the limitations imposed by bilateral agreements for the exchange of air transport rights, time zone differences, and curfews and by nonspecific market forces such as the need to match loads and aircraft size and accumulate loads at particular points and times to maximize load factors.

In this study we are dealing with approximately 250 countries with regularly scheduled air service that contribute to worldwide markets and routings through IAC areas and ocean basins. Because of the multiplicative intercity and intercountry relationships in air traffic generation, this means a minimum of 60,000 intercountry markets and infinitely more city pair markets that may contribute to the peak IAC for any geographic area.

The combined effect of institutional constraints and carrier economics, however, is to restrict long-haul (more than 400 nautical miles) overocean traffic to movements between a few hub airports serving regions that include many ultimate origin and destination cities and countries. Countries seek to yield up the minimum in rights to serve their cities that is necessary to secure the rights sought for their airlines, which are often government owned. This has restricted international agreements to a limited number of gateways, entry points, and routings.

The traffic volumes carried on the aircraft movements originating or terminating at major hub airports cannot be explained solely by the interactive traffic generating capacity of the city pairs linked.

These volumes are the product of entire interregional traffic generation and traffic flows, channeled through particular gateways by bilateral agreements and carrier scheduling practices.

To best accommodate these important characteristics of the analysis, therefore, SRI's forecasting econometric model is an aggregative model rather than a microanalytical market model. The future demand environment is directly conditioned by the forecast rise in the growth of basic variables, population and GNP. These assumptions permit uniform treatment of the forecasting problem and pivot the forecasting effort on predominant statistical relationships that have been demonstrated to prevail in the air transportation marketplace. The disadvantage is that, while aggregate demand conditions may be adequately described, the individual market forecasts lack the benefit of close, analytical scrutiny. This, in turn, makes difficult, without extremely subjective assumptions, identification of the need for wholly new routes not now operated. In the context of the overall work effort, however, close scrutiny was neither possible nor desirable. The forecasting model operates to forecast growth rates only--referenced to scheduled air carrier activity-and functions from a real and known base. The possibility that new routings may come into being, and assessment of their possible impact on peak IACs, can again be considered in subsequent revisions of these forecasts or of the models themselves after experience has been gained with the interactive demand supply modeling system developed in this research.

2. Institutional Environment

The functioning of the international air transport system depends on a complex set of institutional arrangements among governments and carriers and other operators. These arrangements for for-hire services basically determine routes, rates and conditions of carriage. The basic instruments for these institutional arrangements are

bilateral agreements between governments for the exchange of routes and on conditions of carriage and rate and related agreements reached through the International Air Transport Association. Fees for aviation facility use, curfews and other operating restrictions also affect the conditions under which service is offered.

Although this is being challenged, IATA agreements must still be unanimous. The respective governments normally review such agreements. Governments thus exercise considerable influence in IATA rate and related determinations. Governments fundamentally differ on objectives and strategies, whether to maximize short-term earnings in foreign exchange or follow the slower path through developmental rates and industry growth. "Open"[1] rate situations are increasingly common and longer lasting. Charter carriers and many others, particularly in the Far East, function outside of IATA.

Since the content and extent of international coordination of air transportation--within or outside IATA--will influence the future operating environment of the operators in important ways, our forecasting effort required an appraisal of the future nature of the institutional environment of air transportation. Our conclusions are predicated on a weakening rather than increased authority of IATA in air transport affairs and, in the long term, an increased tendency of government actions to permit competitive and capacity growth. We believe that the cooperative structures such as IATA and bilaterals that seek to restrain growth in competition will be weakened by the following forces:

- As small markets grow and can support more direct flight services (as opposed to feeder services), the total number of intercountry agreements will increase.

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1 Failure of carriers to reach agreement through IATA, hence "open," non-IATA agreed rates.

- As markets become larger and more carriers participate in providing service, the number of bilateral agreements that must be struck in each market will increase.

- Continued growth in charter operations and in links between charter and route-type operations will strengthen the drive for provision of charter carrier rights through existing or special bilateral agreements.

- As markets become larger, the returns perceived by a "maverick" carrier investigating opportunities for increasing market share will increase.

- While our forecasts generally predict growth in the air transport industry, growth over the next two decades will occur under unfavorable circumstances relating to energy, environment, carrier borrowing power and airframe technology that will constrain the industry's profitability. This is likely to enhance interest in unilateral strategies as carriers strive for maintenance of market shares.

The recent U.S./British "Bermuda II" agreement is in many senses a contradiction of these assumptions. It has increased constraints on competition and placed restrictions on "fifth freedom" rights. However, there has been loud criticism within Administrative circles as well as from the Congress and industry. The new CAB Chairman holds it up as an example of what not to do.

It is impossible, however, to ignore the existence of other pressures for tightening constraints, such as the demands of the Japanese and the Italians with whom negotiations are virtually deadlocked. So long as the present slowdown in world economic activity continues, there will continue to be conflict between those who would constrain and those who would reduce constraints on aviation activity and capacity offered. In the long run, however, we believe that constraints will be lessened. The Laker Skytrain experiment, the partial liberalization provided by the U.S./ Belgium agreement, and regulatory reform sentiment in the United States are indicators of such developments. IATA is again deadlocked on North Atlantic rates--creating another open-vote situation, and cries are growing louder for IATA's abolition.

We do not regard either institutional or physical constraints as limitations that will restrict long-term growth in air traffic or

aircraft movement. They may affect the spatial dispersion of IACs, but probably not the timing of them within the broad peaks characterizing the major ocean basin flight activities.

An analysis of institutional forces must evaluate the possible impact of U.S. air transportation regulatory reform on international operations, although no proposal that has a serious chance for adoption contemplates significant change in the economic regulation of international operations of U.S. carriers. Pan American has already been awarded some domestic fill-up rights under existing proceedings without benefit of changes in the enabling statutes. Strengthening of the domestic operations of any carrier in the international theater will in the long run augment its competitive impact in international transportation. Measures such as proposals to substantially deregulate both cargo and charter operations and the probable certification for route-type operation of some existing U.S. charter (supplemental) carriers together with any further growth in the part charter movement will further break down the distinction between charter and route-type operations.

The favorable, and perhaps some unfavorable, results of greater freedom in rate experimentation together with route authority changes can be expected to spill over from the domestic to the international arena. Any significant increase in the number of domestic carriers will increase the number of applicants for international service and will intensify the competition of existing U.S. carriers operating domestically and internationally in the international competitive theater. Decontrol may also have some significant technological impacts which we will consider below. The combined impact of the foregoing forces is in our judgment likely to permit or even induce an increase in flight frequencies. The combined effect of these institutional assumptions, including expected growth in charter activity, has been embedded in our model.

Another significant institutional force affecting the type and frequency of operations is the regulations designed to minimize the impact of aircraft noise. Although this is the underlying reason for many curfews at foreign airports, the impact of United States Federal and local governmental regulations is perhaps more far reaching in their effects. They have severely limited supersonic aircraft technological development. For the latter reason they will be considered under the technology discussion below.

3. Technological and Resource Environment

Future aircraft operating patterns and aircraft movement counts will be influenced by the size and physical and economic performance characteristics of the aircraft which will replace current aircraft in the next 20 years.

The advent of jet aircraft in the late 1950s and 1960s brought major gains in maintenance and flight crew productivity as well as passenger convenience and comfort. The introduction of wide-bodied aircraft did not bring comparable gains.

U.S. carriers have historically accounted for 50 percent or more of sales of U.S. air transport and aircraft and engine manufacturers. The low traffic growth in 1975 and most of 1976 and the generally poor U.S. air carrier financial picture reduced new U.S. carrier aircraft orders to a trickle. There has been a recent upturn in orders. This has been induced in part by governmental regulations requiring compliance of existing aircraft fleets with FAA noise regulations over an approximate 8-year period. These new aircraft, however, are not new designs. They are existing technology aircraft.

There is a wide range of technology available, at least on the drawing boards, that could be applied to reduce fuel consumption and

unit flight costs by improving propulsion and aerodynamic efficiency and lift/drag ratios. These include reduced structural weight through use of composites and other advanced materials; improved airfoil design (supercritical wing) that can reduce wing weight and lower drag; engine system improvements such as variable cycle engines; basically more efficient structure and laminar flow control. NASA has a major research program to find ways to reduce energy usage in air transportation. It has financed studies and tests by airframe and engine manufacturers. It has designed a "paper" reduced energy transport for which great savings are claimed. These concepts would produce more noise acceptable aircraft and engines as well.

Airframe and engine manufacturers are conducting in-house as well as NASA and DoD contract research. Both Pratt & Whitney and GE have more fuel efficient engines in the advanced stage. Boeing and McDonnell Douglas have designs for B-707/DC-8 replacements that take partial advantage of new technology. European manufacturers are considering advanced technology aircraft also.

The ability of the air transport industry--including the manufacturing segment--to respond to air travel demands with new, innovative aircraft concepts is constrained by several limitations:

- Fuel costs and availability
- Labor and other costs
- Capital availability and cost
- Ability of the carriers to finance acquisition and integration of significant numbers of new technology aircraft
- The ability of technology to devise aircraft which will continuously increase the productivity of increasingly expensive labor and fuel
- The ability of the airframe and engine industries to finance both the aircraft design R&D and the production and sale of new technology aircraft.

- FAA Noise Regulations and proposed legislation to provide financial assistance for carriers to comply with noise abatement regulations.

Existing timetables for compliance with noise standards, however financed, are likely to result in significant fleet additions of existing technology aircraft since new technology aircraft are not presently available. Some airlines, such as Eastern, are considering the foreign-built A-300. Regardless of the merits of the noise program, the danger of this trend is that there may be significant replacement of older noisier aircraft in U.S. air carrier fleets with existing technology aircraft which barely meet present noise regulations. This might make it difficult, if not impossible, for most of these carriers to buy advanced technology aircraft if such become available in the next decade.

Noise regulations are also restricting operations of the Franco/British SST to the United States, making it difficult to determine the economic viability of the present generation SST. It is therefore necessary to make a judgment whether these constraints will be lifted and whether the aircraft will prove economically viable if permitted to operate between major international air traffic hubs. The present operations into Washington, D.C. area Dulles Airport have met with strong traveler acceptance. Load factors have been good. It is understood, however, that the British and French carriers are both still losing money on these operations.

It is probable that some form of liberalization in economic regulation of U.S. airlines will be adopted during the present session of Congress. The impact of regulatory reform through removal of restrictions on the size of aircraft operated by commuter airlines and the possible reduction in market shares of existing carriers could lead domestic operators to an increased demand for smaller capacity aircraft. Many domestic carriers have already found their B-747s too big for their

route structures under existing regulations and have disposed of them. International operators, however, particularly in light of attempts at limitations on the number of frequencies, and if there is a further pickup in traffic growth, may favor larger capacity aircraft. Manufacturers will find it difficult to design and build aircraft for both requirements and must compromise.

At a recent meeting a United Airlines spokesman declared that their immediate requirement was for a 185-200 passenger replacement for the DC-8s and some B-727s. Other domestic operators have indicated similar interests. On the international scene, Pan American has been replacing larger capacity B-747s with the longer range lesser capacity B-747SP. This has permitted nonstop service in many Pacific markets previously impossible and created a demand on the part of other carriers such as JAL for competitive purchases.

Thus the desire for schedule flexibility and the probable impact on market shares in domestic operations of liberalization of entry of new and existing carriers into new routes on market shares may result in the next generation of aircraft with capacities lower than the B-747 and even the DC-10, L-1011, and even the A-300. It is notable that the A-300 manufacturers are considering a smaller capacity version and other European new technology aircraft emphasis is in the intermediate-size bracket.

4. Assumptions Respecting Future Aviation Environment

In our forecasts we have assumed two scenarios respecting technological change and cost impacts--an "optimistic" and a "pessimistic" set of assumptions. These scenarios differ principally in the possible application of technology to improvements in fuel efficiency and other factors affecting unit operating costs, the extent of the savings that may be attained, and the timing of introduction of advanced technology, more fuel efficient aircraft. The "optimistic"

scenario projects a fuel efficiency gain of up to 20 percent, yielding, after adjusting for increases in aircraft costs, an average total cost saving of 4-5 percent in the 1980-85 period and further gains in the 1985-90 period. These are assumed to derive through introduction of the B-7X7 or B-7N7 or DC-X-200 with GE or P&W 10-ton fuel efficient engines starting in the 1980-85 period and joined by more advanced concept aircraft in the 1985-95 period. During the forecast period, the SST would be operating over the Atlantic and Pacific basins in both the Russian Tu-144 and Franco-British Concorde versions. In restricted markets, the SST would displace flights that currently serve business travel demand, but there would be no net traffic generation effects because this demand is highly inelastic. The "pessimistic" assumption assumes the new Boeing/McDonnell-Douglas aircraft do not enter service until the 1985-90 period, that fuel savings are only 12-15 percent, and that advanced concept aircraft do not appear at all in this time frame. It also assumes very restricted use of the existing SSTs.

If the impact of compliance with noise regulations, however financed, is to cause substantial purchases of present technology aircraft over the next five years, this would push toward the pessimistic scenario and delay the introduction of new technology aircraft at least to the 1985-95 decade. If, however, it proves practical to retrofit or replace aircraft engines to achieve noise compliance, at least the Boeing and McDonnell Douglas B-7X7/B-7N7/DC-X-200 aircraft may find a significant market in this next decade. Regulatory reform in the United States, in the configuration in which it seems most likely to be adopted, would tend to increase the demand for aircraft in this size bracket (175-200 passengers) and, as noted, European designs are aimed at the same capacity market. Although there has been some recent interest shown in a 600-passenger aircraft, we do not believe that there will be a significant market for a large-capacity aircraft (700-1,000 passengers) during the next 20 years. We do not expect a large market for the present generation SSTs (Russian or Franco/British) under either

scenario even if U.S. noise restrictions are resolved. We think that developmental problems and investment fund availability as well as the probable need for U.S./European cooperative agreements will delay development and introduction of a second generation, probably reasonably fuel efficient SST until beyond 1995.

Fuel costs are assumed to continue to increase but to generally match cost-of-living increases. Labor rate increases are expected to reach cost-of-living rates and then stabilize also. Capital and other costs are likely to increase somewhat faster than general price levels. The combined effect of labor and other nonfuel cost increases will be to make total flight costs for any given size of aircraft rise slightly more rapidly than the general price level. In our sensitivity analysis, this percentage was varied, in real terms, from 0.0 to 1.5 percent on a compounding per annum basis.

5. Application of These Assumptions to the Forecasts

Our model permits incorporation of alternative assumptions concerning the foregoing parameters in several ways:

- The flight-cost relationship recognizes that the cost of a flight increases somewhat less than in proportion to the size or the stage length of the aircraft. If a new airframe design significantly altered these cost elasticities, they could be input directly in the model formulation.
- The flight cost model is parameterized directly for a fuel price index in real terms.
- The flight cost model is parameterized directly for a unit or fixed cost growth facter to represent (in real terms) the change in the overall labor and capital costs of operating a flight.

The translation of the technological and resource future of the air transportation industry into parametric assumptions then permits the model to select the likely rate of change in the gauge of the aircraft fleet, the average fare, and the flight frequency that would be observed in each market.

B. Air Traffic Activity Forecasting System

This section provides a brief overview of the forecasting system as well as the forecasting and counting methodology used by SRI to achieve the objectives of this research effort. A more detailed discussion of the forecasting system and methodologies is provided in APPENDIX II, Section 2.

1. Forecasting System

The forecasting system was developed to estimate peak instantaneous airborne counts (IACs) of flights over any geographic area, such as an ocean basin, and its geographic subareas. To achieve this objective, it was necessary to consider the influence of five different kinds of traffic and the aircraft movements operated to accommodate them. These include "scheduled" traffic (passenger and cargo), charter traffic (civilian and military--MAC) and not-for-hire (general aviation) traffic.

Since the only comprehensive, consistent and reasonably reliable data on overocean aircraft movements are the schedules set forth in the Official Airline Guide, these data were used as a basis to drive our IAC counting model. All other traffic and aircraft movements have been related to the "scheduled" traffic.

Our forcasting system consists of four modules[1] or components: the ICAO Data Processing Module (DPICAO); the Forecasting Module (FORCAS); the OAG Data Processing Module (DPOAG); and the Instantaneous Airborne Counting Module (FIRS). Figure 37 is a flow diagram illustrating the relationship between the module. The primary function of each module is described below:

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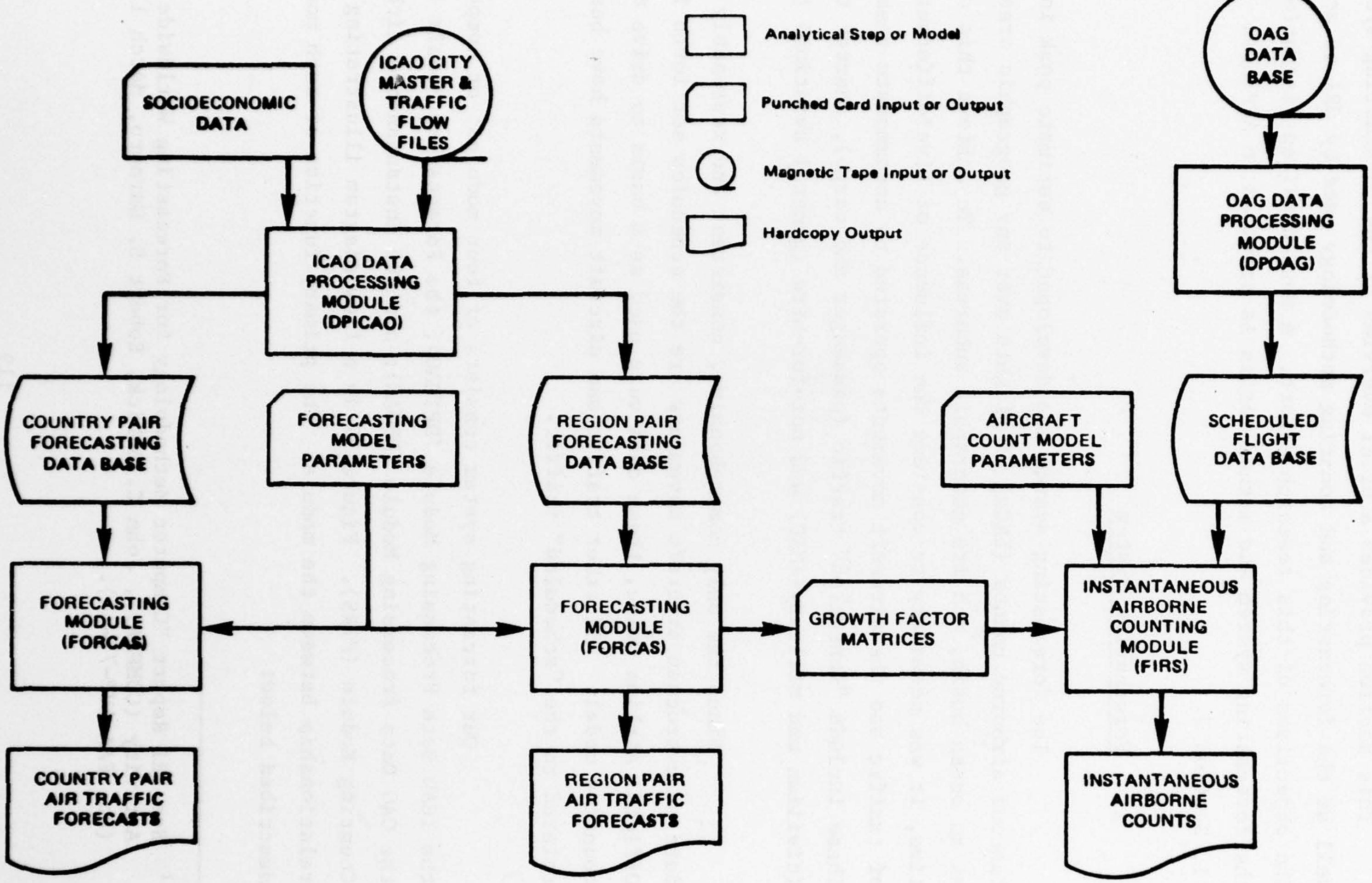
[1] See SRI Report "Computer Methodology for Forecasting Worldwide Aviation Activity (COMFAA)", John C. Bobick, Robert S. Garnero, March 1977 (No. FAA-AVP-77-14).

Figure 37 AIR TRAFFIC FORECASTING SYSTEM



- ICAO Data Processing Module--Sorts and compiles ICAO air traffic data and socioeconomic data for input into the FORCAS module.

- Forecasting Module--Generates growth rates and forecasted levels for various air traffic parameters pertaining to "scheduled" air carrier activity (passenger and cargo). Through a series of interacting models, all other types of traffic and aircraft movements are related to "scheduled" traffic in order to estimate forecasts of air traffic activity for "nonscheduled" traffic (charter and general aviation). The module then generates regional growth factors, which are ratios of forecasted levels of activity to base scheduled levels for input into the FIRS counting module.

- OAG Data Processing Module--Sorts and complies OAG data which provides itinerary data (i.e., flight frequency, origin and destination, etc.) for each "scheduled" flight by a commercial air carrier. The resultant data base serves as the basis for determining the spatial and temporal distribution of air traffic activity and is an input to the FIRS module.

- Instantaneous Airborne Counting Module--This module consists of a flight-tracking model that flies aircraft through specified areas (defined by latitudinal and longitudinal boundaries). The model asks the location of each flight every six minutes. These counts are then aggregated into 24 groups of tens to determine the peak hour instantaneous airborne count for ocean basins and IAC areas within them. The IACs represent boundary estimates of activity contributed by all traffic categories analyzed in this research.

2. Forecasting Methodology

Separate models were developed for estimating and projecting "scheduled" civilian passenger, charter, all cargo, military charter and general aviation traffic. All of the models relate to a market-derived econometric model that permits the association of changes in influential variables with changes in the use of air transportation. Forecasts, therefore, can be revised and updated by inputting current socioeconomic, institutional or technological facts and assumptions that may produce different projections of traffic and aircraft movements.

This methodology is inherently most applicable to the "scheduled" civilian passenger and cargo transport markets that have been exhaustively examined. It is less so to military air charter and not-for-hire markets for which little statistical data on movement patterns are available, and little is known concerning the stimuli that determine the need for such traffic movements and the desire lines affecting their choice of routings and operating times.

We approached this data deficiency problem by assuming that all "nonscheduled" services, performed by "scheduled" and "nonscheduled" airline operators and by general aviation, operated in a diurnal pattern analogous to that of the "scheduled" airlines' services. This is a "worst" case assumption because it produces maximum peaking characteristics, placing maximum demand on a communication facility. We perceive this assumption as a boundary assumption and believe it will probably over-estimate the peak, but properly locate the peak in space. The assumption will then provide a useful upper bound in basin and IAC area activity measures for the peak periods.

The validity of this assumption is supported in a general way by limited data made available to SRI by certain carriers. An inspection of these flight data that describe the charter operation of several major scheduled carriers (TWA, American, and Braniff) and two major nonscheduled operators (Trans International Airlines and Saturn Airways) indicated that the charter passenger activity entailed itineraries and equipment similar to that observed in the "scheduled" markets.

Even if the assumption of synchronous behavior of "scheduled" and "nonscheduled" activity is incorrect, its impact will be minimal. This is because the level of "nonscheduled" traffic is probably not sufficient to substantially influence the timing and location of flight

activity peaks over the various regions due to the relatively pronounced peaking observed for "scheduled" services. Analysis of the peaking characteristics of "scheduled" services for all three basins shows that considerable shifting of individual schedules around the basin peaks could occur without significantly affecting their temporal location or general shape.

a. Forecasting Aircraft Movements Associated with Passenger Travel

Forecasting of aircraft movements associated with passenger travel depends on a simultaneous interaction between two models, reflective of supply and demand functions. This is due to the underlying assumptions in our approach that, in addition to the socioeconomic and demographic characteristics of the origin and destination, tripmaking decisions are influenced by costs (fare), quality of service and flight frequency, while price and frequency, in turn, depend on demand for tripmaking.

While fares in the long run tend to be responsive to carrier financial condition, they lag cost changes as was well demonstrated during the height of the fuel price escalation. Because of manufacturers' leadtime, financial limitations and carriers' own fleet planning processes, fleet increases lag demand increases. Because of a combination of forces, the profit maximizing behavior of air carriers affects the response of aircraft movements to changes in tripmaking behavior or costs.

The demand model thus relates "scheduled" passenger trips to average fare, number of flights, aircraft size and to the products of the origin and destination respective regional per capita incomes and populations.

The supply model is based on assumed carrier profit maximization in relating costs to the flight offered. The model recognizes

that air carrier costs depend on the number of flights, average aircraft size, stage length and fuel price per gallon. Air carrier frequency and price adjustments were assumed to occur with a lag, as noted. These models are described and explained in more detail in APPENDIX II. They reflect rates of growth rather than absolute levels. Among parameters reflected in the models are: returns to scale, price elasticity of demand, flight elasticity of demand, income elasticity of demand, population elasticity of demand, size elasticity of flight costs, distance elasticity of flight costs, fuel price elasticity of flight costs, elasticity of fare with distance, and the fraction of desired fleet that can be adjusted (retired) in one year.

The validity of the model was evidenced by the very high level of the t statistics of the individual parameters and coefficients, and by the consistence of sign and magnitude of parameters and coefficients with assumed relationships. Finally, the model was successfully used to "backcast" historical data on North Atlantic traffic.

b. Forecasting Aircraft Movements Associated with Civilian Charter Traffic

Civilian charter traffic was treated as another fare class of traffic competing in part for the same market pool. The charter passenger is distinguished by a high elasticity of fare and service demand as indicated by a willingness to accept a different quality of scheduling and convenience for a fare differential. Lacking the detailed itineraries respecting charter flights available on scheduled operations through the OAG, the forecasting techniques for charter operations are much less precise.

We have assumed that the institutional and market forces will be favorable to charter development, particularly as group inclusive tours (GIT) and movement of charter passengers on "scheduled"

flights (part charters) increases and the differences between "scheduled" and charter carriers disappear. Our model recognizes the higher elasticity of demand for charter service. However, charter traffic is substantially treated as a function of "scheduled" passenger traffic.

c. Forecasting Aircraft Movements Associated with All-Cargo Traffic

Because overocean cargo shipments respond to basically the same economic forces as passenger traffic, and all-cargo movements are subject to the same--if not more restricted--bilateral and marketing/scheduling pressures, we related the growth rate of all-cargo flight activity to that of "scheduled" passenger flights.

d. Forecasting Aircraft Movements Associated with General Aviation Traffic

Not-for-hire (general aviation) operations presented extraordinary difficulties, as had been anticipated in our proposal for this research. The absolute lack of data on general aviation international flight patterns is of concern to governments, manufacturers, and user organizations such as the National Business Aircraft Association, the U.S. and International Aircraft Owners and Pilots Associations and other groups. It is likely to be many years, however, before they succeed in persuading ICAO and their member states to establish procedures to collect the required data.

In the absence of usable data we had to rely on general measures of general aviation activity derived from ICAO sources. We also used FAA data and estimates of U.S. domestic general aviation activity and private studies. These analyses indicated a correlation between general aviation activity and the same income and population data that generate the demand for airline service with which not-for-hire services, to some extent, compete. A model was developed from

available data relating general aviation activity to "scheduled" passenger service.

e. <u>Forecasting Aircraft Movements Associated with Military Charter</u>

The military do have data on the diurnal patterns of Military Air Charter (MAC) operations and their departure and arrival characteristics. After much "we will/we won't" negotiations, no such data were forthcoming. We had to improvise with what we had. We have assumed a no-growth situation based on 1974-75 levels and related military movements to scheduled operations. As noted earlier, should military traffic expand, it will displace civilian traffic. The worst case was adopted—that MAC peak IACs coincide with "scheduled" passenger traffic IACs. This is the same assumption made with respect to civilian charter, cargo, and not-for-hire traffic.

3. IAC Counting Methodology

The SRI methodology for estimating peak IACs is based on a computerized flight-tracking model that enables the determination of the density of aircraft movements over a particular region at specified points in time, and the rates at which such aircraft enter and leave the regional airspace during these times.

Figure 38 diagrams the IAC estimation process. The OAG data provide flight departure and arrival times, type (size) of aircraft and origin-destination coordinates in latitude and longitude. Coordinates in latitude and longitude are inputted to establish Atlantic, Pacific and Indian basin and IAC area boundaries. Since computer constraints limited us to rectangular shapes, all IAC areas are rectangles.

Other model inputs are takeoff time, elapsed time, takeoff day for each flight over each region plus the forecast aircraft movement

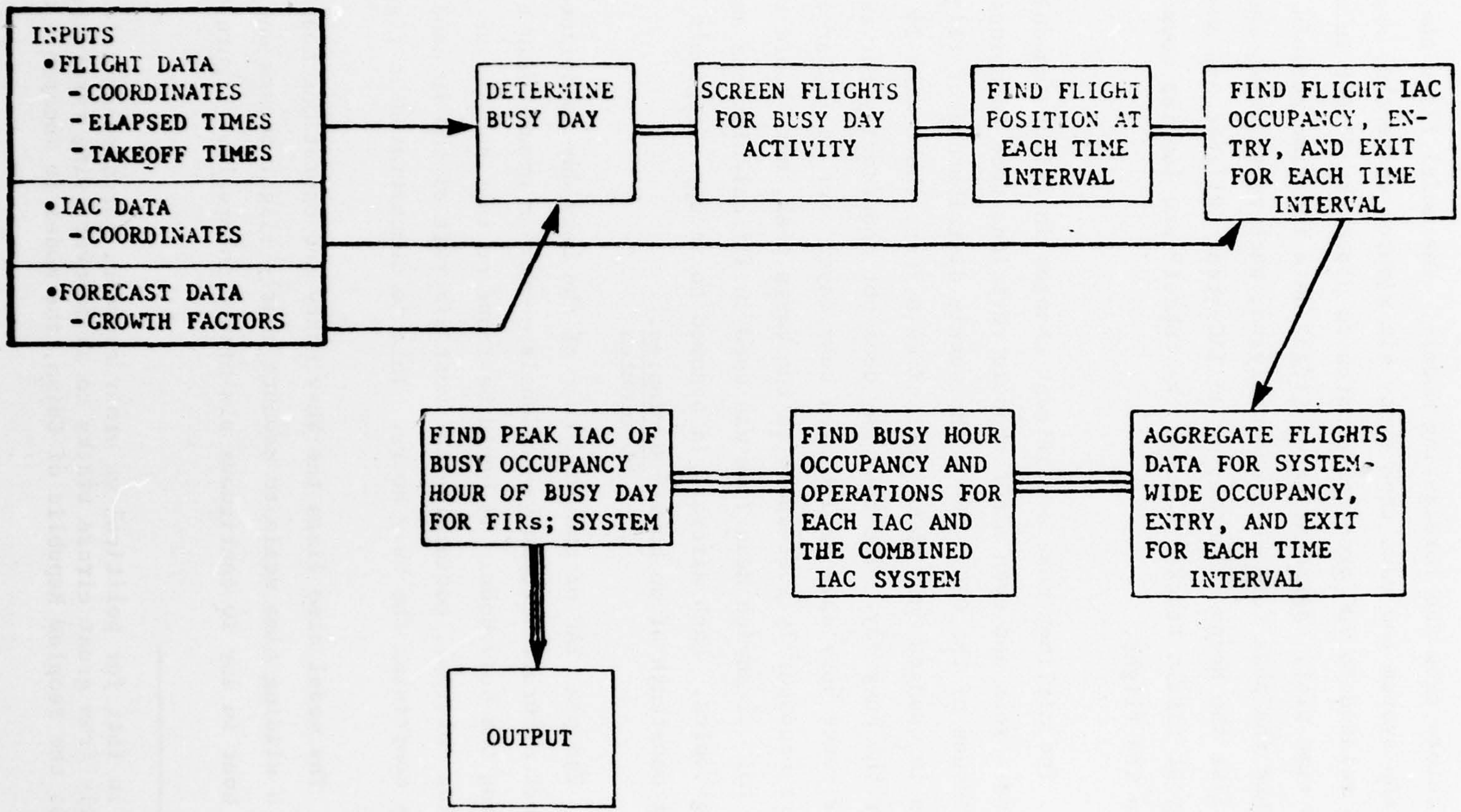


FIGURE 38 THE IAC ESTIMATION PROCESS

growth factors from the forecasting models. The model flies the aircraft through the system and asks them every six minutes where they are. These data are related to IAC area coordinates to place the flight in a geographic and time slot. Aggregation of flight data for time periods establishes the peak for the areas analyzed, such as an ocean basin, a subarea like the North Atlantic, or an IAC area. Flights are assumed to follow great circle tracks[1] between the takeoff and landing coordinates making up its flight.

The airlines make significant changes in flight schedules only four times a year and even minor shedule revisions tend to coincide with monthly issues of the OAG. Since the weekly distribution of flight schedules is changed only about four times a year, there were 28 candidates for the busy day. The busy day does not necessarily correspond to either route busy days or IAC area busy days. Nor do IAC area peak busy hours necessarily correspond to the basin peak, nor should they be expected to. Greenwich Mean Time was used in all calculations and resulting tables. Each aircraft is assumed to occupy a region's airspace for one-tenth of an hour-- $\frac{6 \text{ minutes}}{60 \text{ minutes}}$.

The peak IAC of the busy hour of the busy day is defined to be the highest aircraft occupancy--or density--over an ocean basin or IAC area during the busy hour. It would be found on that particular snapshot, or counting interval, containing the most aircraft of the 10 candidate snapshots comprising the busy hours. This is demonstrated in Figure 39.

The model also lists the busy entry and operations hours and provides a sliding time scale to measure hourly flight counts and find the busy hour in any 10 contiguous six-minute intervals. Figure 40

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[1] Where in fact for political or other reasons, carriers deviate significantly from great circle tracks to avoid overflying restricted areas such as the Peoples Republic of China, the model is incapable of detecting this.

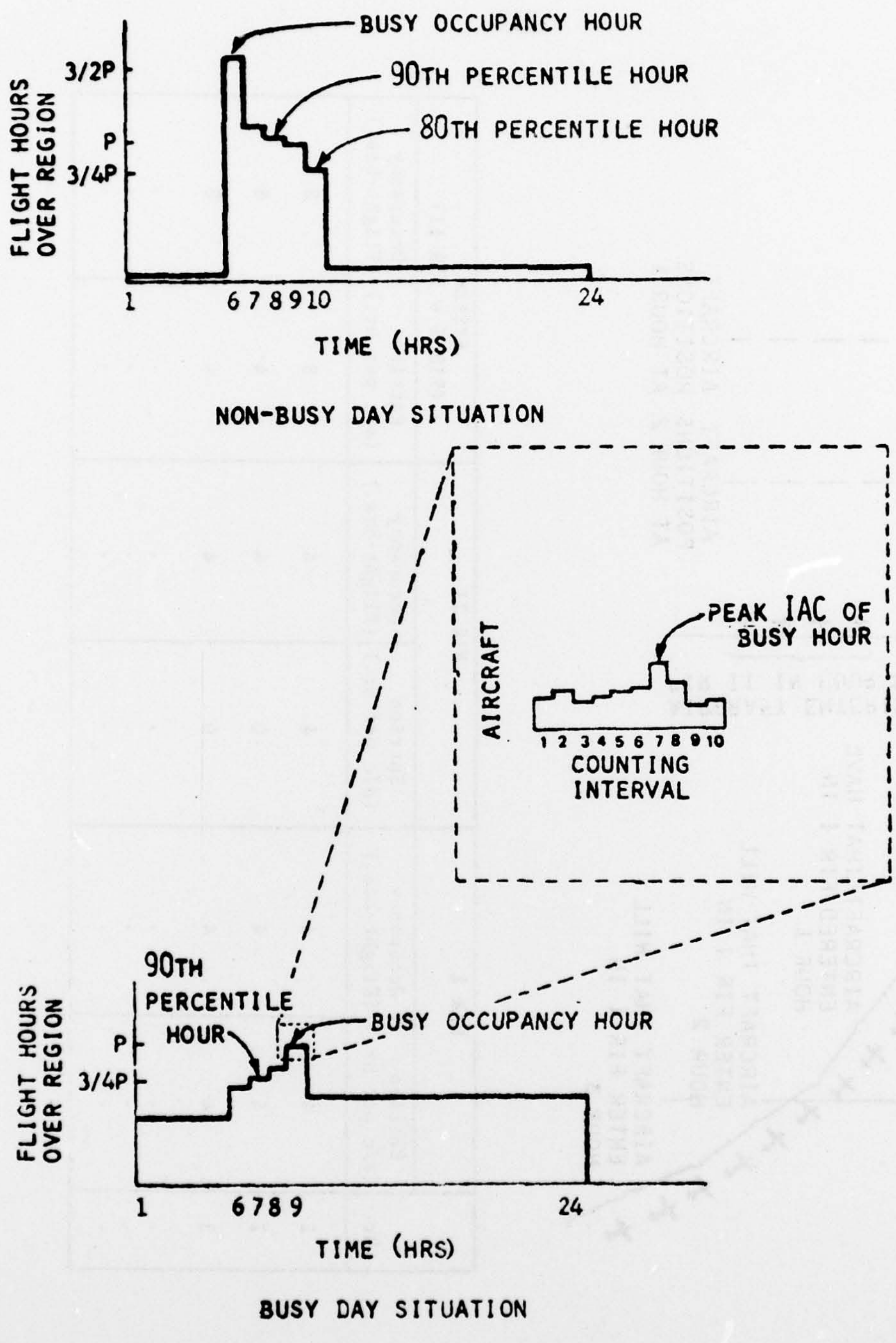
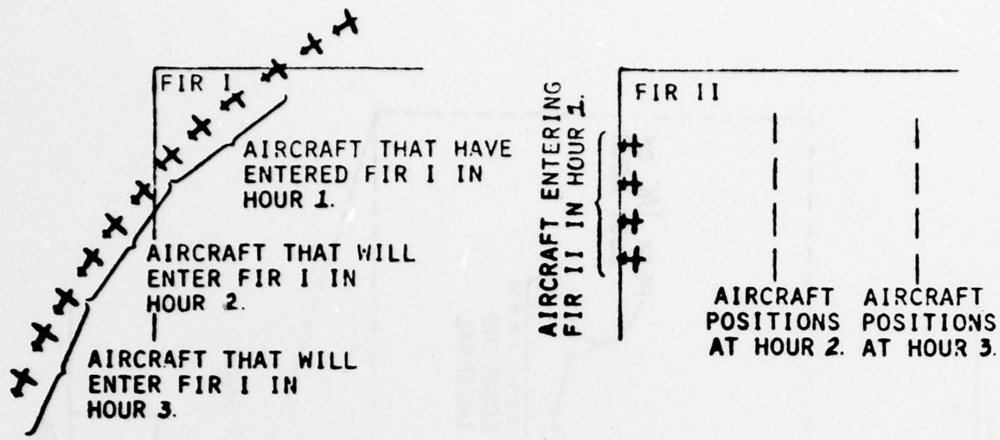


FIGURE 39 BUSY OCCUPANCY HOUR OF BUSY AND NONBUSY DAYS



	FIR I		FIR II		SYSTEM (FIR I + FIR II)	
Hr.	Entries (a/c per hr.)	Occupancy (Flight-hrs.)	Entries (a/c per hr.)	Occupancy (Flight-hrs.)	Entries (a/c per hr.)	Occupancy (Flight-hrs.)
1	4	4	4	4	8	8
2	4	4	0	4	4	8
3	4	4	0	4	4	8
⋮	⋮	⋮	⋮	⋮	⋮	⋮

FIGURE 40 VOLUME/DENSITY RELATIONSHIPS

shows how the busy entry or exit hour can differ from the busy density hour described earlier, if one stream of traffic cuts across the corner of an IAC area and another, perhaps smaller, stream flows through it.

C. Sensitivity Analysis

As with any large-scale forecasting effort, the many aspects of uncertainty at each step in the forecasting process must be assessed and their influence on the outcome evaluated. We accomplished this by performing a sensitivity analysis, testing our model's input parameter assumptions and traffic peaking assumptions.

1. Testing of Input Parameter Assumptions

Our modeling effort limited the parametric assumptions to nonfuel costs, gross national product, population and fuel prices. This was purposely done because:

- These parameters were found to be crucial variables in determining the supply and demand conditions affecting air travel. They are independent variables and can be varied to reflect alternative scenarios. This makes the model extremely flexible and useful.

- By limiting the number of parametric assumptions, the impact of changing assumptions on the forecasting results can be minimized.

A sensitivity analysis measuring the effect of large errors in parameter assumptions on the accuracy of the forecasts was performed. The results of this test showed that large errors in the assumed parameters can have a significant effect on an individual forecast. For example, a 1 percent error in the growth rate of fuel prices can result in a 0.5 percent error in the forecast annual rate of growth of "scheduled" flights.

The risk of these effects is involved in any forecasting effort, yet there are several aspects of our approach to the problem which mitigate the importance of errors:

- The socioeconomic growth rate assumptions are developed from United Nations data which have been proven useful historically.
- The law of large numbers suggests that since we are forecasting on a region-to-region basis, these aggregate forecasts will be more accurate than country-to-country forecasts.
- Because we are forecasting in five- or ten-year periods rather than on a year-to-year (or month-to-month) basis, short-run inaccuracy is not crucially damaging to the forecast product.

To accommodate the possibility that all our assumptions are incorrect, we have allowed our forecasting system to accept different parameters resulting in "high" and "low" forecasts. This widens the range of uncertainty to some degree. The sensitivity of the model is such that the high or optimistic traffic estimate for the basin is roughly 1.7 times that of the pressimistic estimate. Thus, in spite of relatively generous ranges of parameter assumptions, we have been able to produce controlled bounds on our traffic estimates. This is largely an advantage of the type of model that we have used which permits limiting the number of input parameters. More ad hoc models tend to generate wider bounds[1] which are of less utility in decisionmaking processes.

2. Testing of Traffic Peaking Assumptions

The forecasting methodology assumes that the behavior of all "nonscheduled" traffic components is roughly synchronous with "scheduled" patterns. This assumption was made because very limited data exist on the hourly and diurnal patterns of "nonscheduled" activity. These data are essential to the IAC counting module.

[1] The UCLA Delphi study for the Climatic Impact Assessment Program, for example, produced high and low cases that differed by a factor of ten. (USDOT, CIAP Monograph 2, 9/75 pp. 8-67).

To assess the effects of this assumption, two separate model runs were conducted:

- An "all-traffic" case which assumes that "all traffic" has a temporal distribution similar to the "scheduled" traffic.
- A "scheduled" traffic case which does not include any "nonscheduled" traffic in the peak counts.

The effect of the different extreme assumptions is to compound the "reasonable" range of variation in the peak traffic statistics. Thus, in addition to a ratio between high and low estimates of about 1.7 caused by the assumed variations in the socioeconomic data, there is a range of variation of 1.6 to about 1.9 caused by the different peaking assumptions. Thus our sensitivity analysis concludes that for peak IAC counts, a reasonable high count is roughly 2.7 and 3.2 times the reasonable low count for traffic in the Atlantic basin over the full 20-year period.